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ABSTRACT

Presented is part one of a training program designed to educate students and individuals in the importance of conserving energy and to provide for developing skills needed in the application of energy-saving techniques that result in energy efficient buildings. Alternatives are provided in this program to allow for specific instruction in energy-saving methods and procedures, or for integration with construction courses. It may also be used for self-paced instruction. The materials are divided into three parts: (1) Understanding and practicing energy conservation in buildings: (2) Determining amount of energy lost or gained in a building: and (3) Determining which practices are more efficient and installing materials. Major topics presented in part one include understanding the importance of energy, developing a concern for conserving energy, understanding the use of energy in buildings, care and maintenance of energy efficient buildings, and developing energy-saving habits. (Author/DS)

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Providing for Energy Efficiency in Homes and Small Buildings

Part I

OCT 6 1980

PROVIDING FOR ENERGY EFFICIENCY IN HOMES AND SMALL BUILDINGS

This instructional program was developed for the Department of Energy under Contract No. EX-77-R-01-6065 by the American Association for Vocational Instructional Materials.

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Preface

This is a training program designed to educate students and individuals in the importance of conserving energy and to provide for developing skills needed in the application of energy-saving techniques that result in energy-efficient buildings.

Upon successful completion of this course of instruction, a student will be able to perform at the job entry level.

Alternatives are provided in this program to allow for specific instruction in energy-saving methods and procedures, or for integration with counstruction courses. It may also be used for self-paced instruction.

When used in the classroom, the unit can be integrated with the building construction curriculum, or it can be taught separately.

A teacher guide and student workbook are available to supplement the basic manuals. The resource person should consult the teacher guide and follow procedures given therein.

The material is divided into three parts:

PART ONE: UNDERSTANDING AND PRACTICING ENERGY CONSERVATION IN BUILDINGS.

PART TWO: DETERMINING AMOUNT OF ENERGY LOST OR GAINED IN A BUILDING

PART THREE: DETERMINING WHICH PRACTICES ARE MOST EFFICIENT AND INSTALLING MATERIALS.

Introduction

Almost everyone is aware of the increasing rate of energy use and the rapid decline in non-renewable resources (Figure 1). They agree that something should be done to conserve energy, but they are uncertain about what to do.

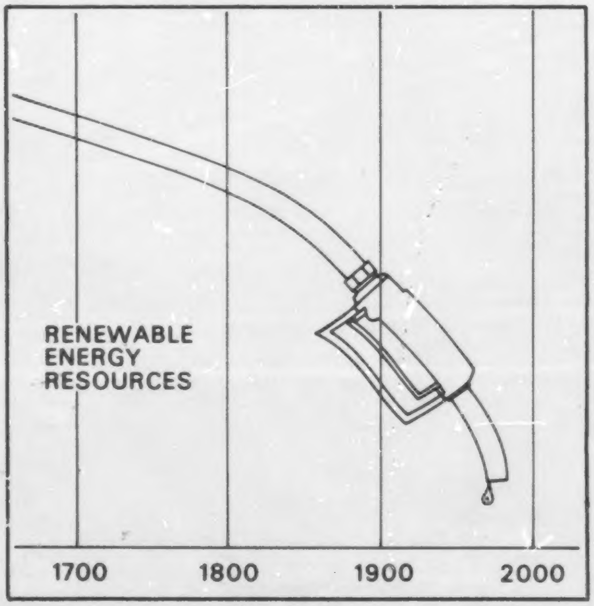

FIGURE 1. The world supply of nonrenewable energy resources is declining rapidly.

How many times have you heard someone say, "I know I should be saving energy, but I am not sure how to go about it. And besides, what little energy I could save would be so insignificant, it wouldn't count." The truth is that the small amount each person saves is significant. The only way a great amount of energy can be saved is for everyone to make a concerted effort to conserve as much energy as possible.

A good place to start is in your home. About one fourth of the energy consumed in the United States is used in homes (Figure 2). Another 14% is consumed in commercial buildings.

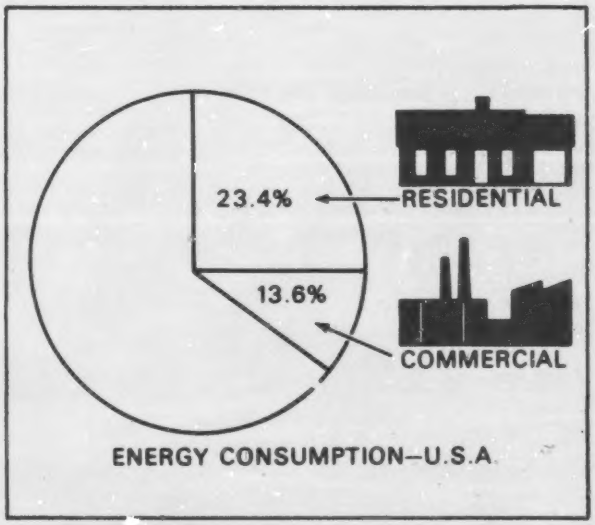

FIGURE 2. Approximately 24% of energy consumed in the United States is used in homes and 14% in commercial buildings.

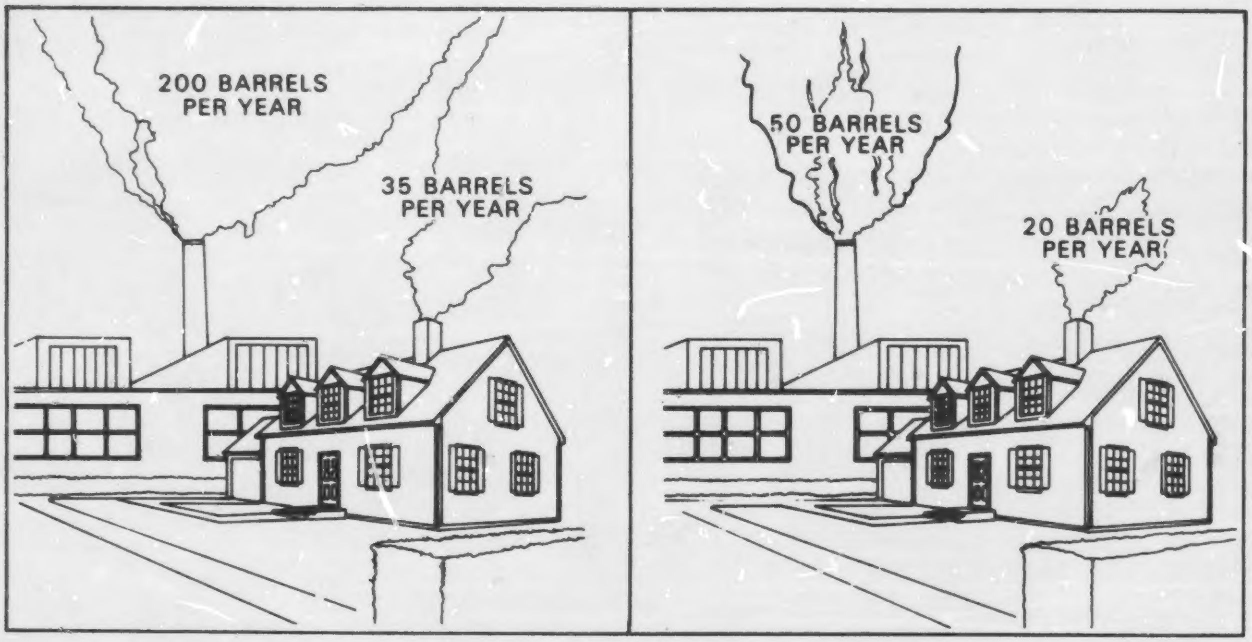

FIGURE 3. Two buildings may look alike, but one may be much more energy efficient than the other.

The average home in the United States uses about 35 barrels (equivalent) of crude oil per year. With proper conservation practices, it is possible to reduce this consumption by at least 15 barrels per year. Multiply 15 barrels times 80 million homes in the United States and you see that more than 1 billion barrels (equivalent) of oil can be saved per year. Similar results are possible with commercial buildings.

Then the question arises, "How does one save energy in a home or a building?" It is true that you cannot tell by looking at a structure whether it is energy efficient (Figure 3). The answer lies in proper design and construction, equipment selection and installation and the operation of the building.

These and other factors are explained in this course. Once you have mastered the techniques, you will not only know what to do to save energy, but how to do it. You may be able to do your own building and help others as well.

You may wish to engage in the business of building or retrofitting homes and buildings for energy efficiency. A person who is skilled in the construction and repair of energy-efficient homes and buildings is much in demand. The material in this program will help you prepare for such a job (Figure 4).

ENERGY EFFICIENT HOMES INC.

FIGURE 4. Building and retrofitting energy-efficient homes and small buildings is good business.

This training program is divided into three parts. They are as follows:

PART ONE: UNDERSTANDING AND PRACTICING ENERGY CONSERVATION IN BUILDINGS

PART TWO: DETERMINING AMOUNT OF ENERGY LOST OR GAINED IN A BUILDING

PART THREE: DETERMINING WHICH PRACTICES ARE MOST EFFICIENT AND INSTALLING MATERIALS

Part I

Understanding and Practicing Energy Conservation in Buildings

Understanding the importance of saving energy and ways to conserve in buildings are explained under the following headings:

I. Understanding the Importance of Energy.

II. Developing a Concern for Conserving Energy.

III. Understanding the Use of Energy in Buildings.

IV. Care and Maintenance of Energy-Efficient Buildings.

V. Developing Energy-Saving Habits.

I. Understanding the Importance of Energy

How many times each day are you bombarded with the term "energy?" "Energy" is on the tips of our tongues—the topic of everyday conversation. It is blasted from the television sets and printed in books, newspapers and magazines. Energy is needed for life. It always has been. It is energy that is essential to the basic necessities of life: food, shelter, and clothing (Figure 5).

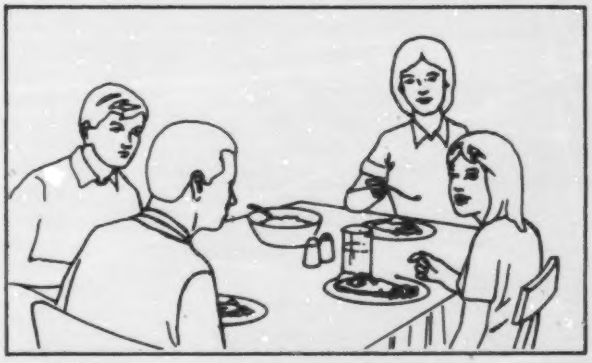

FIGURE 5. Energy is essential to the basic necessities of life.

In recent years, dependence on energy has increased. Our modern technological society demands more than the basic necessities of life. Some of those demands are convenience, comfort, health and recreation. It takes a lot of energy to provide power for industrialization, mechanization, transportation and space heating and cooling of buildings. Such expanding use of energy has created some difficult economic, social and environmental problems. Wise and efficient use of energy is essential. More time is needed for the development of alternate sources.

People have become accustomed to using as much energy as they wish for work and leisure activities. Very little thought has been given to the idea of energy's being wasted. Now, the traditional sources of energy, fossil fuels, are becoming scarce. Everyone must think seriously about conserving energy and finding new sources to meet the needs (Figure 6).

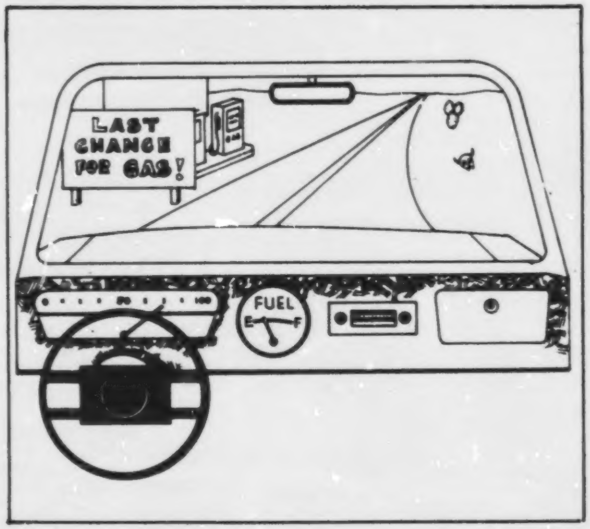

FIGURE 6. Energy supplies are becoming critical.

This is your opportunity to learn how to make wise decisions in the use of energy. First, determine the importance of energy in your life and in the lives of others by answering the questions discussed under the following headings:

A. What is Energy?
B. What are the Primary Known Sources of Energy?
C. What are the Major Uses of Energy?

A. What is Energy?

"Energy" means different things to different people (Figure 7). To the athlete, it means strength, vitality and endurance. To the auto mechanic, energy means power to propel. To the chef, it means heat for cooking. Energy can be defined best by describing it. From your study of this section, you will be able to define energy in its different forms and under different conditions. Descriptions are given under the following headings:

1. Forms of Energy.
2. Conditions of Energy.
3. Conversion of Energy.
4. Laws of Energy.

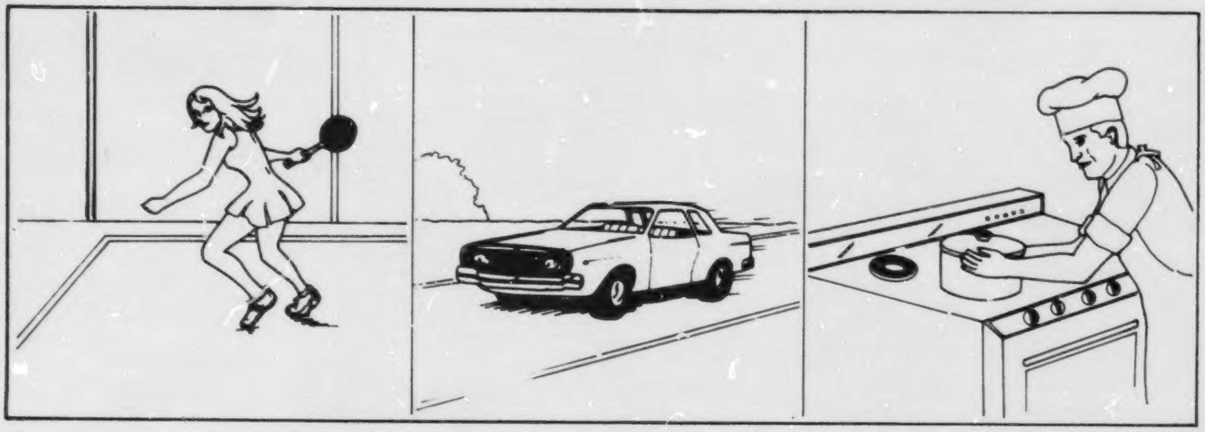

FIGURE 7. Energy means different things to different people.

1. FORMS OF ENERGY

The principal forms of energy are as follows:

a. Mechanical Energy

Mechanical energy is that which is produced by moving objects and those that have a potential for motion (Figure 8) or for interrupting motion.

The term is used to describe the use of energy in mechanical form: transporting things, rearranging, or distorting them. The most common and important characteristic of energy is its capacity to do work.

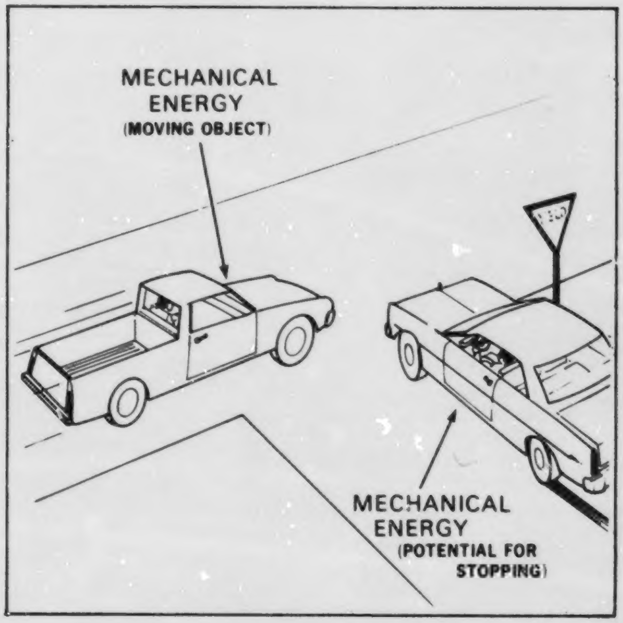
MECHANICAL ENERGY (MOVING OBJECT)
MECHANICAL ENERGY (POTENTIAL FOR STOPPING)

FIGURE 8. Mechanical energy is that produced by moving objects and objects that have potential for motion or for interrupting motion.

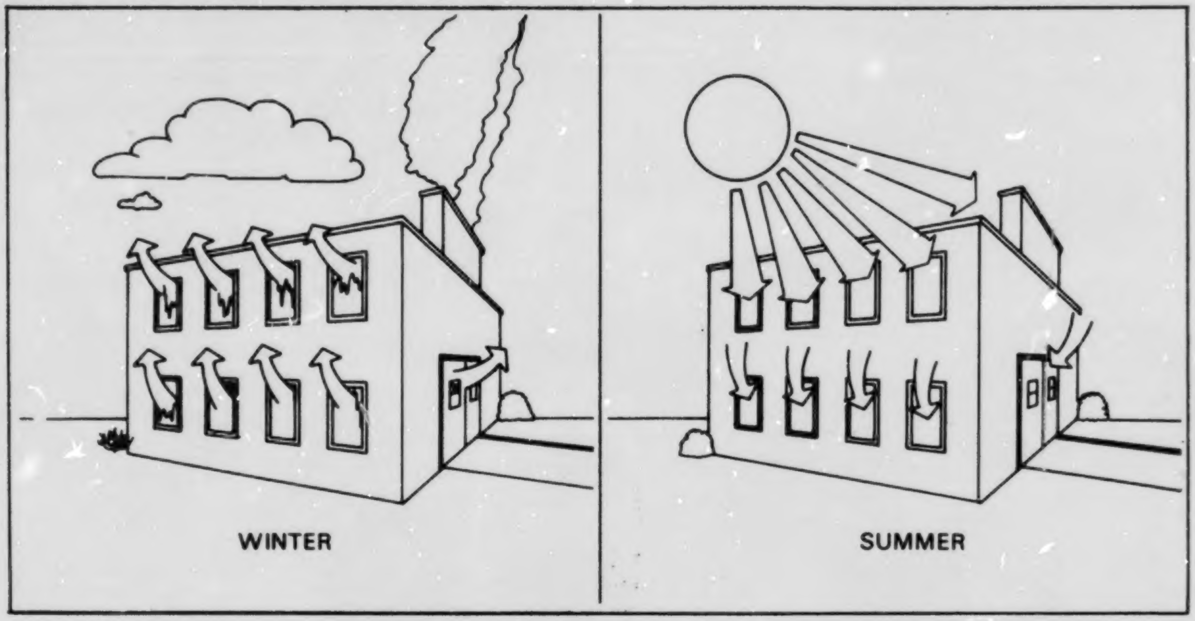

FIGURE 9. Heat energy seeks an equilibrium by moving from a higher temperature to a lower temperature.

b. Heat Energy

Heat energy is that form of energy which is most important to environmental control in buildings (Figure 9). Heat energy always travels from warm to cold. So in winter, heat escapes from the inside of your heated house to the cold outdoors. In summer, heat moves from the hot outdoors to inside your house.

Heat is usually a by-product of other forms of energy, such as friction caused by rubbing two objects together. Heat is also given off when matter is changed by combustion. Much energy is wasted, as in the generation of electricity. For example, cooling towers are used to help dissipate heat from the steam generators (Figure 10).

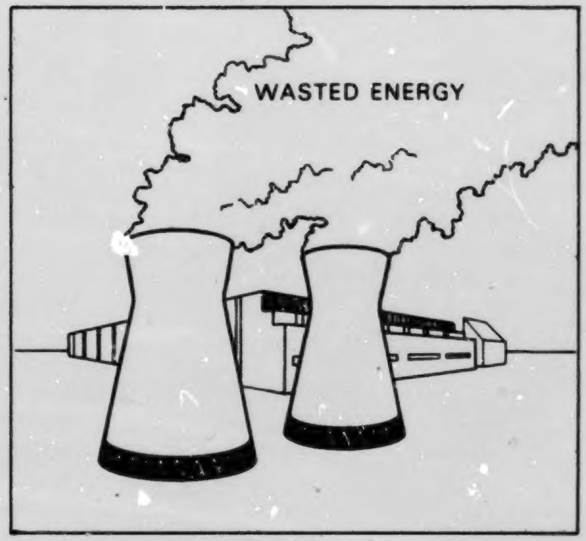

FIGURE 10. Cooling towers for dissipating heat at an electric power plant.

Combustion is used to convert matter into heat for buildings. Fossil fuels are converted into heat, ash and gases by combustion. As a result, heat is given off (Figure 11).

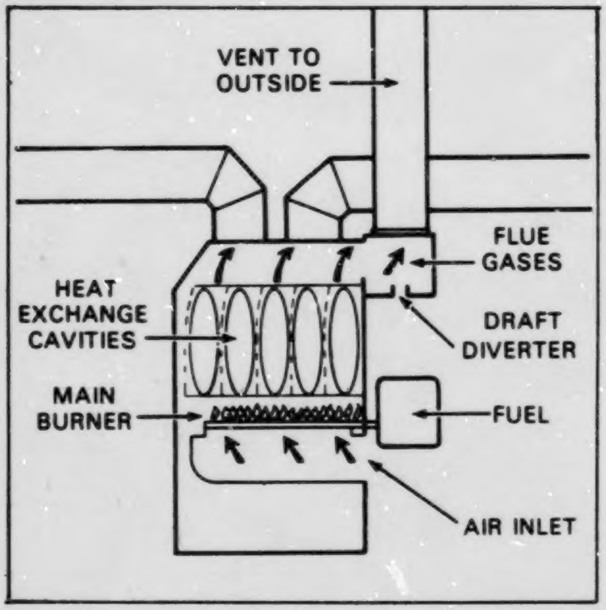

FIGURE 11. Heat is provided for buildings by converting matter in a hot-air furnace.

In order to help you provide for energy efficiency, you need to understand three methods of heat flow:

(1) HEAT FLOW BY CONDUCTION. Heat flows readily through dense materials such as metals, stone and masonry (Figure 12).

This heat flow through the solid is by conduction.

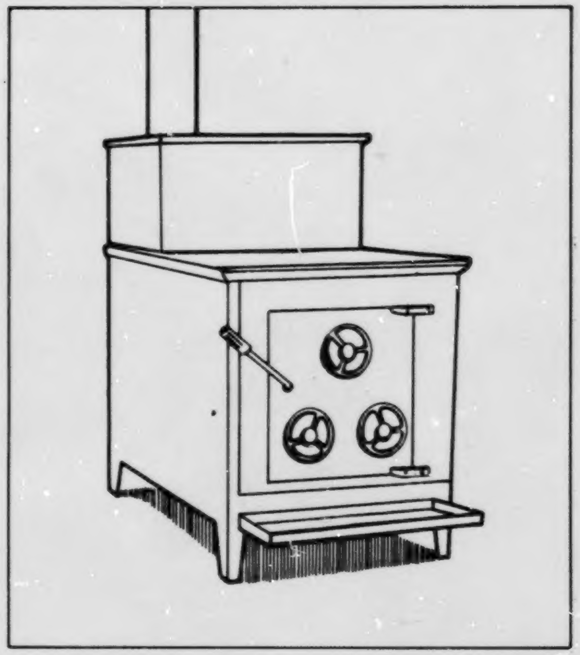

FIGURE 12. Heat flows through metals by conduction.

(2) HEAT FLOW BY CONVECTION. Heat flows by convection when it is borne by a moving medium such as air. If you have a hot air heating system, the heat will be transferred by convection from the register (Figure 13).

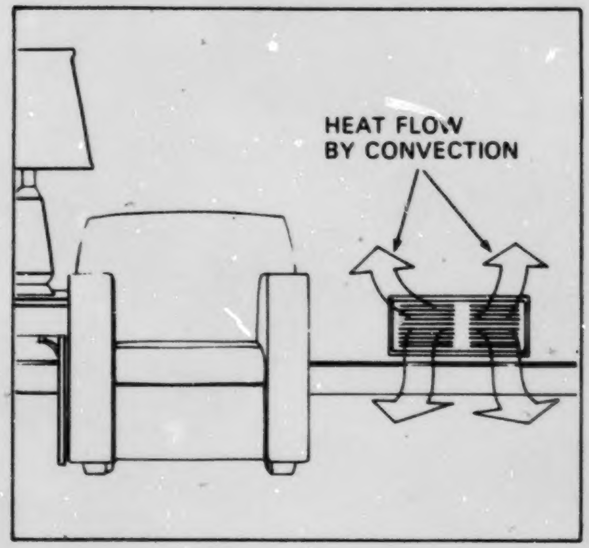

FIGURE 13. Heat flows by convection through a medium such as air.

(3) HEAT FLOW BY RADIATION. Heat flows by radiation directly from a light source by rays, such as those of the sun or from an open fire (Figure 14).

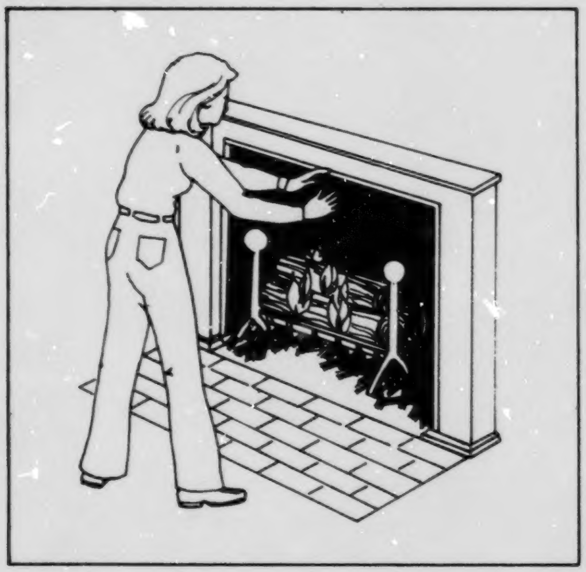

FIGURE 14. When you warm yourself before an open flame, the heat flows by radiation.

c. Light Energy

Light energy is also thought of as radiant energy. Plant and animal life depend on radiant energy from the sun (Figure 15).

d. Chemical Energy

Energy is released from materials by chemical reaction. The food we eat and the fuel we burn are converted to heat energy by chemical changes. Chemical energy is released when materials change molecular structure (Figure 16).

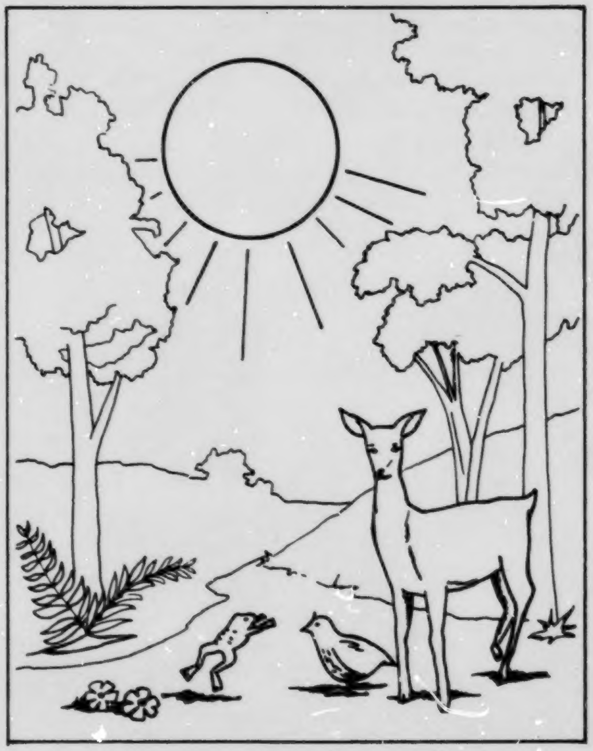

FIGURE 15. Radiant energy from the sun sustains plant and animal life.

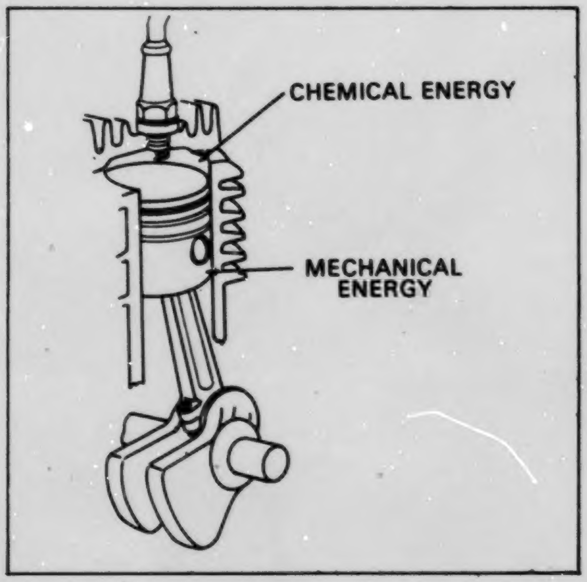

FIGURE 16. Fuel burning in a cylinder is converted to mechanical energy.

e. Electrical Energy

Electrical energy is generated by mechanical generators turned by some outside source (Figure 17). The primary source is steam turbines, heated by fossil fuels.

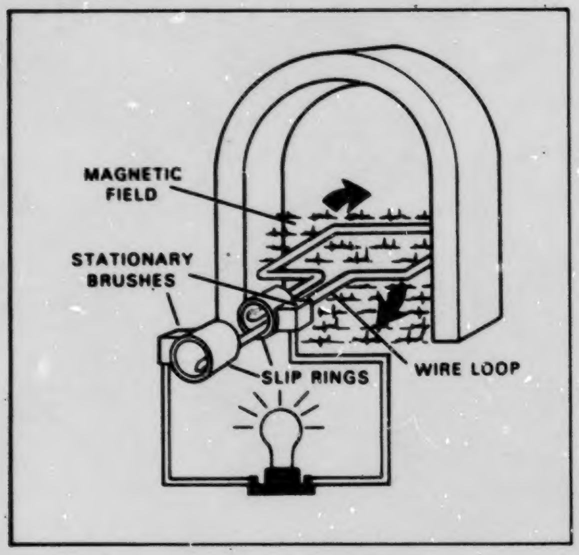

FIGURE 17. As the wireloop turns and cuts the magnetic lines of force, electric current flows in the circuit.

f. Nuclear Energy

Nuclear energy is derived from the splitting of the nucleus of atoms or uniting two nuclei. Energy is given off in heat.

Splitting the nuclei of atoms is called "fission" and uniting the nuclei of atoms is called "fusion" (Figure 18).

2. CONDITIONS OF ENERGY

For the purpose of scientific discussion and use, energy is separated into two conditions. They are as follows:

a. Kinetic Energy

Energy in the form of motion, heat, light or sound is called kinetic energy. It is energy in motion or at work like a snowball rolling downhill (Figure 19).

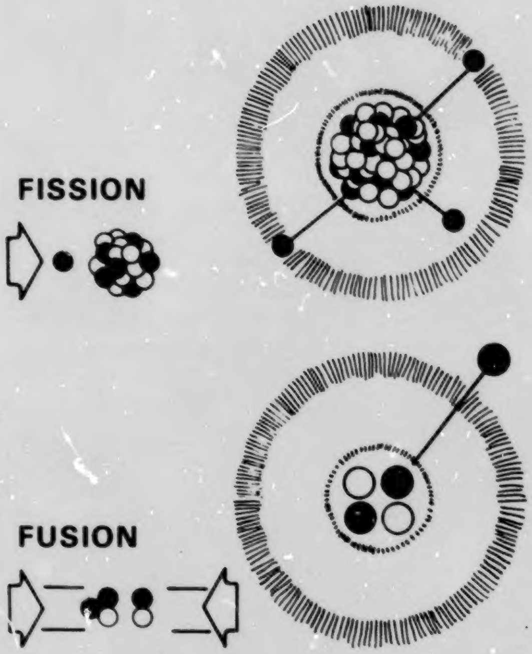

FIGURE 18. A tremendous amount of energy is released when the nuclei of atoms are split or combined.

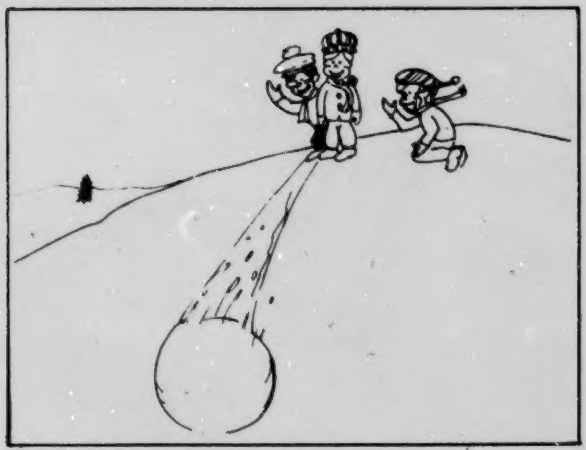

FIGURE 19. Kinetic energy is that produced by an object in motion.

This is the condition in which energy is used. The purpose is to do something to matter such as move it, illuminate it or warm it. For example, a moving car has kinetic energy. The electrons flowing through a heating element and photons of light coming to us from the sun are forms of released or flowing energy--not stored. (Figure 20).

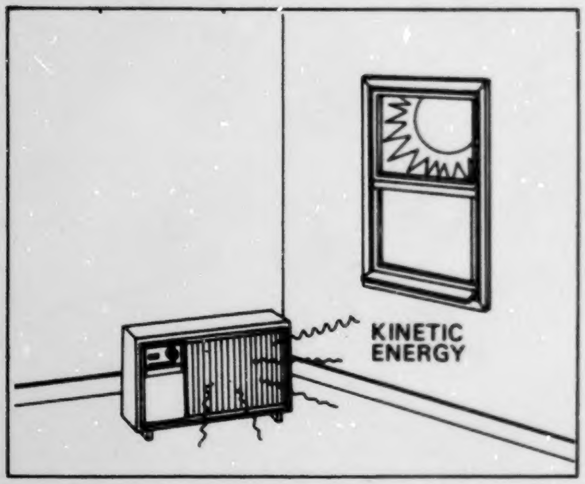

FIGURE 20. Electrons flowing through a heating element or light from the sun represents released energy.

Kinetic energy may be stored, but only temporarily. It must be trapped or insulated, such as in the flywheel of an engine or heat energy stored in Thermos bottles (Figure 21).

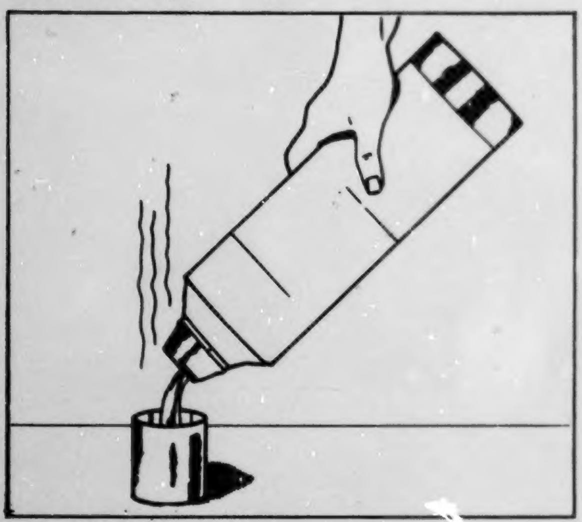

FIGURE 21. Heat energy stored in a Thermos bottle is kinetic.

b. Potential Energy

Potential energy is the capacity of an inactive object to produce motion such as a snowball being held on a hillside (Figure 22). It may also be used to denote the latent power of a substance to produce heat, light and other forms of energy.

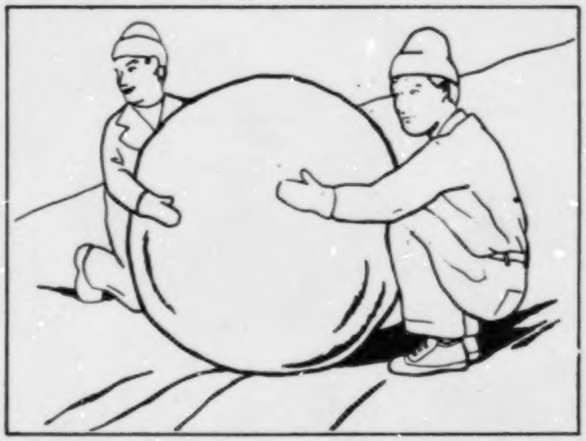

FIGURE 22. Potential energy is the capacity of an inactive object to produce motion or work.

Potential energy is stored energy and it is in this form that it is dug from mines, pumped from wells, shipped and stockpiled. It may be in such forms as wood, coal, oil, gas or water behind a dam (Figure 23).

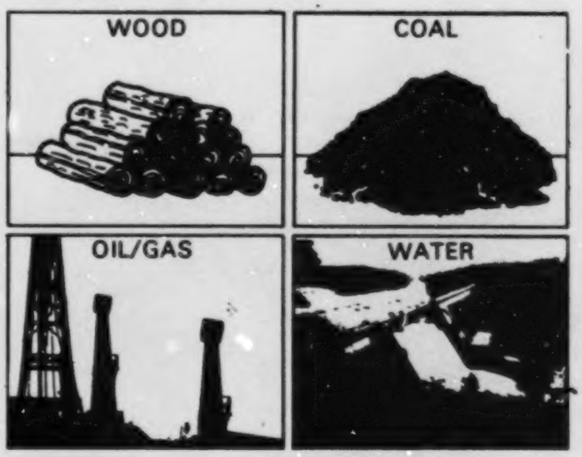

FIGURE 23. Potential energy may be stored in such forms as wood, coal, oil, gas or water behind a dam.

Potential energy storage is more permanent than kinetic energy. It is accomplished within the structure of matter. Energy is stored, for instance, in the carbon atom and released when that carbon atom is combined with an oxygen molecule in the chemical reaction we call burning (Figure 24). The product of this reaction is carbon dioxide, CO_2. The nucleus of the uranium atom stores energy that is released when that nucleus is split in two in the fission reaction.

A simple way to store energy is to lift something away from the earth. For example, energy is stored when water is pumped to the top of a water tower, then converted to the kinetic energy of motion when the water is allowed to run through the pipes to its final destination.

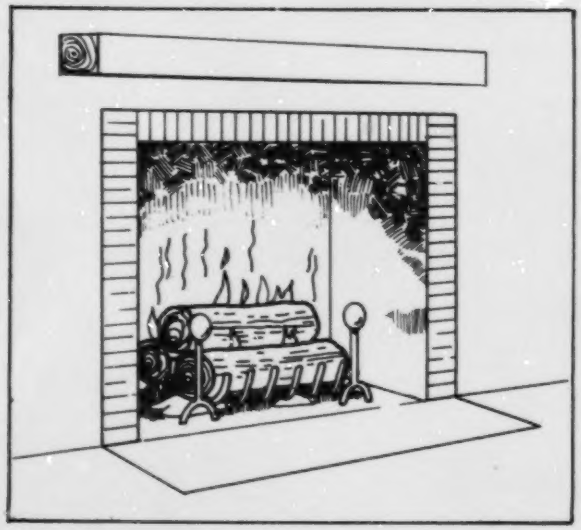

FIGURE 24. Potential energy is stored in wood and released as kinetic energy when combined with oxygen and burned.

3. CONVERSION OF ENERGY

Energy presents itself in various ways such as light, heat, sound, magnetism and motion. Actually these observable characteristics of energy are the result of energy's being converted from one form to another (Figure 25).

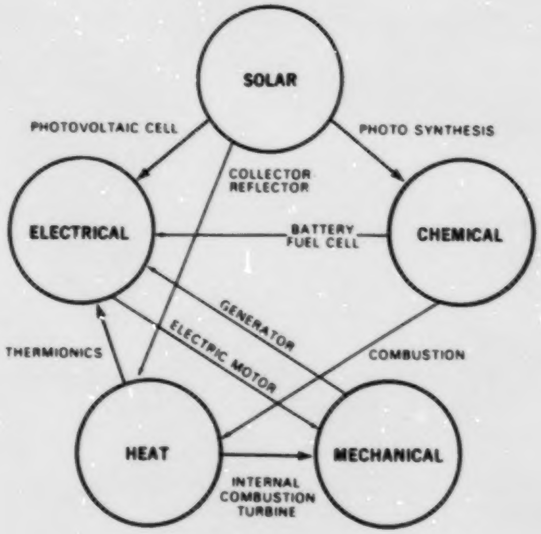

FIGURE 25. Energy has its usefulness in being converted from one form to another.

The sun is our primary source of energy. It is continuously releasing heat, light and other wave energy from its nuclear and chemical reaction. An engine burns fuel, produces heat, sound and motion. Chemical conversions of the food we eat enables our bodies to keep warm and to give off heat. A series of energy conversions in a steam-generating power plant are shown in Figure 26.

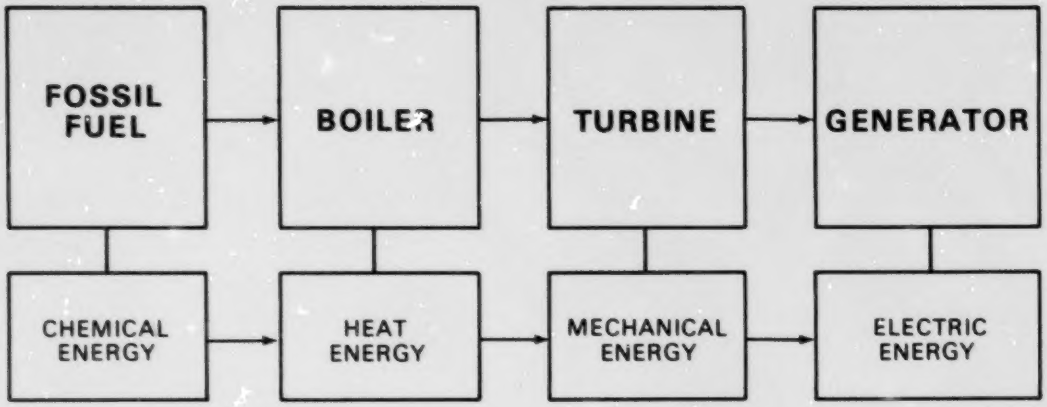

FIGURE 26. Energy conversions in the process of producing electricity in a steam-generating plant.

A fuel, such as coal, is burned to release heat which changes water into steam. The steam is directed against turbine blades to produce mechanical energy in the form of a rotating shaft. The rotating shaft drives an electric generator which produces electricity.

The more energy-to-energy conversions between the primary source and the final end use, the greater the losses. Therefore, the lower the overall efficiency of the system.

4. LAWS OF ENERGY

The basis of our knowledge of energy flow and change is summed up in two laws of thermodynamics:

a. Conservation of Energy.
b. Efficiency of Energy.

a. Conservation of Energy

The First Law of Thermodynamics, also known as the law of conservation of energy, states:

> Energy can be neither created nor destroyed.

Therefore, when a plant, animal, human being, or machine uses energy for food or to do work, the energy is not consumed or destroyed. It is simply transmitted to another place or changed to another form. If, for example, you eat a candy bar containing 150 calories, it is converted to other forms of energy. It may become heat energy in your body, power your muscles, or be used in your brain. It may be stored as fat. It probably does some of all these things, but it always remains 150 calories of energy.

Another example--a piece of wood--can be burned only once, but the ashes of the wood, plus the heat and smoke in the surrounding environment, although scattered, have the same amount of energy as the original piece of wood (Figure 27).

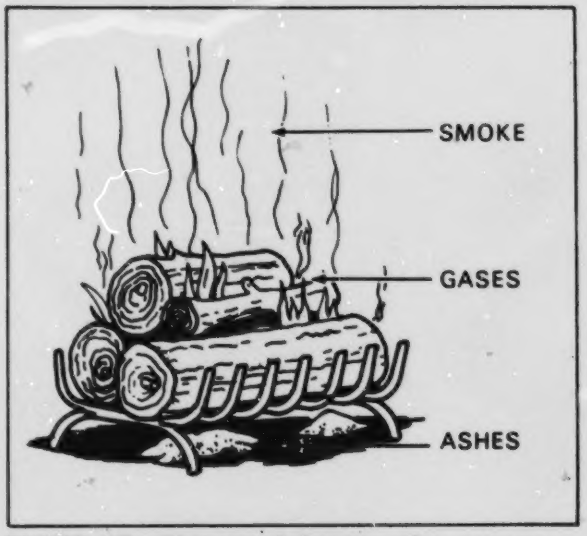

FIGURE 27. When wood burns, the energy is changed to heat, smoke, gases and ashes.

b. Efficiency of Energy

While energy is never destroyed, once used, it no longer has the same value. This is the Second Law of Thermodynamics which describes what happens when energy is used:

> In any conversion of energy from one form to another, some of it becomes unavailable for further use.

Each time energy changes form on earth, its quality is further degraded and it eventually escapes into space, largely as low-grade, dispersed heat. The term used to describe such energy losses is "efficiency." Efficiency is a comparison of energy put in versus energy taken out (Figure 28). The efficiency of a machine or an engine is the ratio of the useful work output to the total energy input. The formula is as follows:

$$\text{Efficiency} = \frac{\text{Useful work output}}{\text{Total work input}}$$

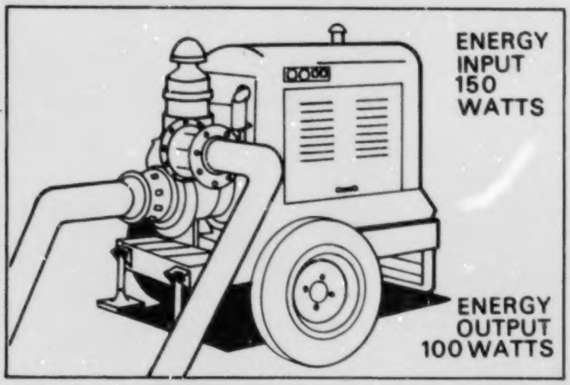

FIGURE 28. Energy input is usually greater than energy output.

For example, the heat given off during the operation of a power plant, engine, motor or other conversion devices, is not often, or easily, captured and put to use. This is a major form of energy waste (Figure 29). Energy conversion systems which are designed by people are usually much less efficient than those in nature. Also, they are also usually more harmful to the environment.

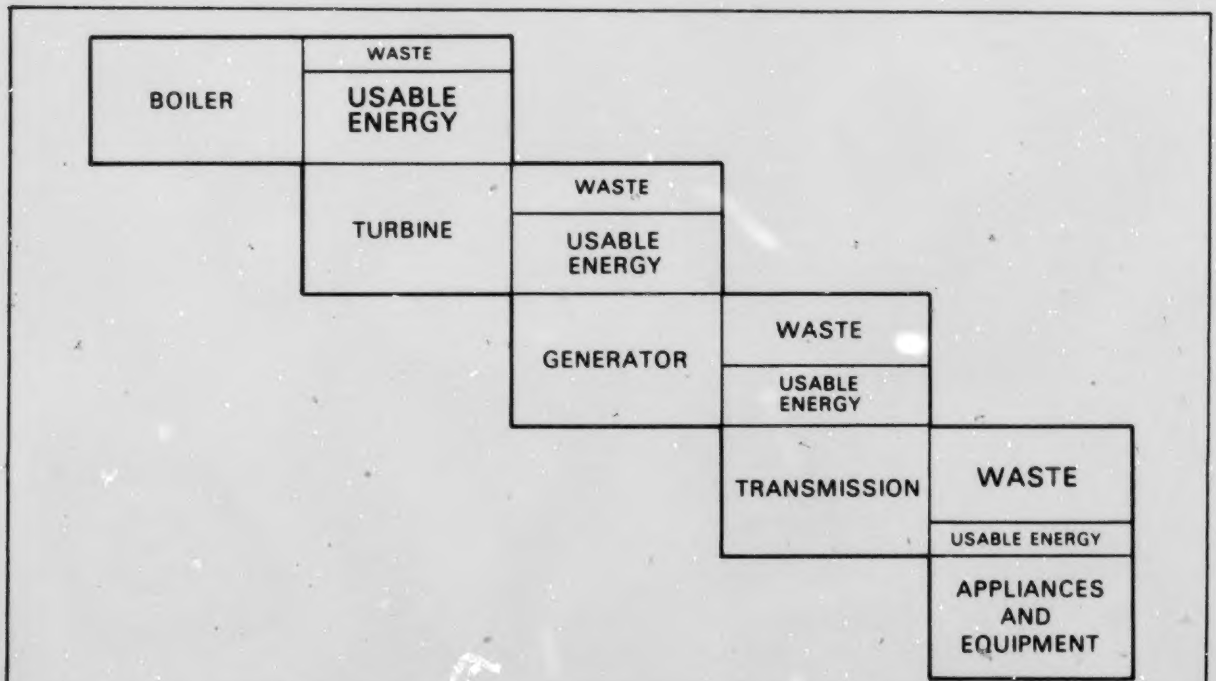

FIGURE 29. Energy loses some of its usefulness (quality) each time it is converted to another form.

B. What are the Primary Known Sources of Energy?

All energy resources belong to one of two groups--renewable or non-renewable resources. For example, the sun is a renewable resource; so is water. Fossil fuels—coal, oil, and gas--are non-renewable. They were produced over millions of years by vegetation under pressure in the earth's crust and heated by the sun. Uranium, another important energy resource, is also non-renewable.

Most energy that is used today comes from fossil fuels which are non-renewable. Only 3.8% is derived from nuclear sources--which are also non-renewable.

Coal, oil and natural gas are the primary sources of energy (Figure 30). Most electricity comes indirectly from these sources. About 14% is generated by water power.

What about wood? Wood was never used in large quantities as fossil fuels are today. But it was the primary source of energy for the first 100 years of this country.

Before 1850, wood was the primary fuel used in the United States. Wood was used to heat homes and buildings as well as to generate steam for locomotives, ships and factory machinery. After the Civil War, our nation experienced great industrialization and tapped coal as the major fuel for industrial growth. Coal replaced wood in the factory, in transportation systems and supplemented wood as a home heating fuel.

From the birth of our nation until the 1860's, whale oil was the principal source of fuel for artificial lighting and lubrication. From 1820 to 1860, the price of whale oil rose about 400%. Demand exceeded supply.

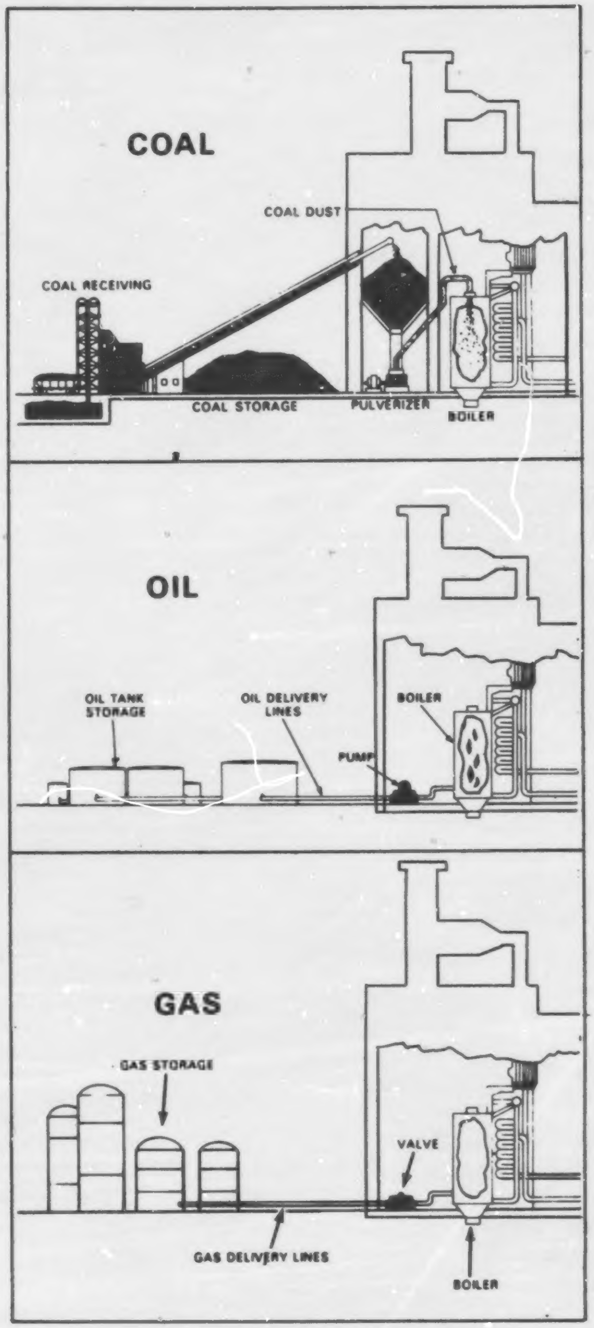

FIGURE 30. Coal, oil and natural gas are primary sources of non-renewable energy.

*U.S. News and World Report, March 19, 1979.

In 1859 E. L. Drake drilled the first commercial oil well in the United States. Oil was refined to produce kerosene, a fuel for lamps, and lubricating fluids. Although oil had a slow start as a fuel, the development of the automobile and later the airplane brought it into demand.

With Edison's ingenious invention, the light bulb, a need for electricity evolved. Electric current was first produced by steam-generating plants powered by coal.

Natural gas was originally discarded as an unwanted by-product from oil drilling. As pipeline technology improved, more factories and homes switched to this cheaper, cleaner source of energy.

Presently our major energy sources are the non-renewable fossil fuels (Figure 31). In the United States, an expanding population began to demand industrial products and the change to fossil fuels occurred at an accelerated rate. In 1850, coal accounted for only 10% of American fuel consumption, wood for 90%. But by 1885, coal passed wood, and by 1910, the situation of 1850 was reversed; coal 90%, wood 10%. After World War I, petroleum was twi[illegible] important as wood, although co[illegible] still predominant. But by 194[illegible] petroleum fuels began to outran[illegible]

Now there is an imbalance of [illegible] ased on domestic supplies (Figure 31).

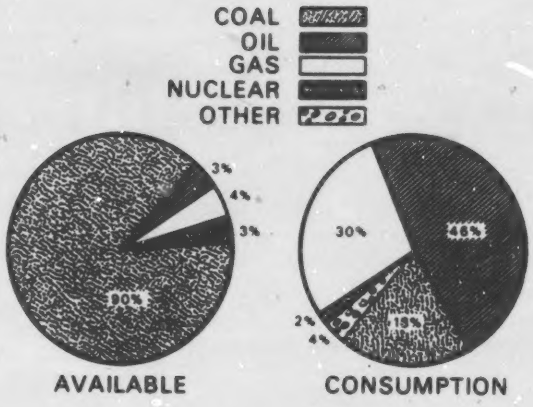

FIGURE 31. Oil and natural gas provide 76% of our energy while coal represents 90% of available resources (National Energy Outlook, DOE, 1976).

C. What are the Major Uses of Energy?

It has already been stated that homes consume about one fourth of the energy used in the United States. Industry accounts for 36%, transportation 26% and commercial buildings 14% (Figure 32). All of these are important to the general economy.

Americans have more than doubled their total energy consumption in the last 25 years. Demand for energy, per capita, has increased by 50% during that time.

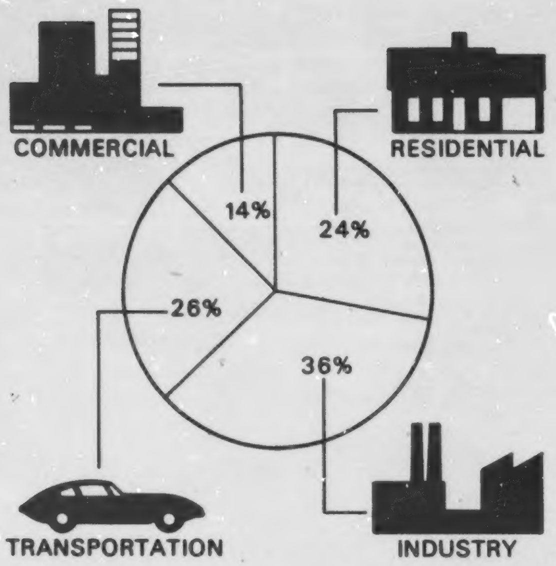

FIGURE 32. Relative uses of energy (Tips for Energy Savers, DOE, 1976).

Heating is the largest single source of energy consumption in the building sector. Water heating and various appliances are next. Some of the factors which can greatly influence the consumption of energy for these purposes include:

- Building design and location.
- Insulation, storm windows, weatherstripping.
- Maintenance of heating and cooling systems.
- Furnace and appliance efficiency.
- Thermostat settings (heating and cooling).
- Fuel and electricity prices.

These factors involve both conservational attitudes and economic incentives. You can readily see from available information that energy efficiency in buildings can have a major impact on energy consumption and, as a result, economic well-being in the United States. Our best sources of energy in the near future are conservation and efficient use of our resources.

II. Developing a Concern for Conserving Energy

Why all the fuss about saving energy? Are we really running out of fuel? Yes, fossil fuels (coal, oil and gas) are rapidly diminishing in supply. In the past 50 years, more coal and oil have been consumed than in the previous history of the earth (Figure 33).

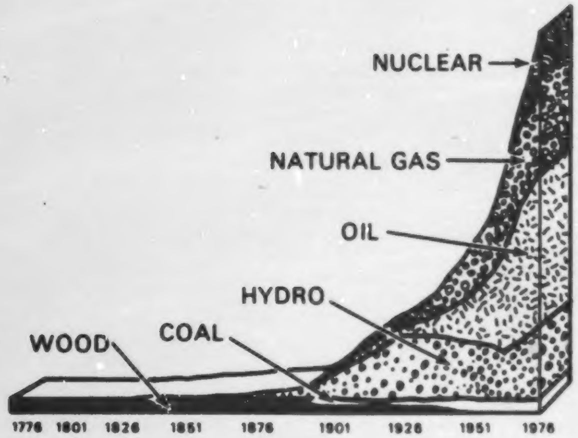

FIGURE 33. Relative consumption of energy in the United States (Chart, Energy History of the United States, DOE, 1975).

Since World War II, modern technology has endowed man with countless mechanized tools and conveniences which were not dreamed of a century before. Most of our advances in technology have resulted from an apparent abundance of fossil fuels. Utility companies reduced rates to high volume consumers. Between 1950 and 1975 the energy consumption in the United States almost doubled. We have become a high-energy-consuming civilization in a very short time.

No one really knows how much fossil fuel is still available, or how much energy can be gained from alternate sources. Best estimates, however, seem to provide for little time to develop alternate sources. To extend this time, a conservation program is necessary. Waste must be held to a minimum without appreciably disrupting production or changing lifestyle.

The importance of an energy conservation program is discussed under the following headings:

A. How Long Will the Present Supply of Fossil Energy Last?
B. What are the Prospects for Alternate Sources of Energy?
C. What Effect May the Energy Situation Have on an Individual?

A. How Long Will the Present Supply of Fossil Energy Last?

No one really knows how long the present supply of fossil fuel will last. It appears there will be enough fuel for this and another generation or two. The fact is, however, that the rate of consumption is increasing in the United States--about 5% per year. The amount available within the United States is diminishing by about the same rate (Figure 34).

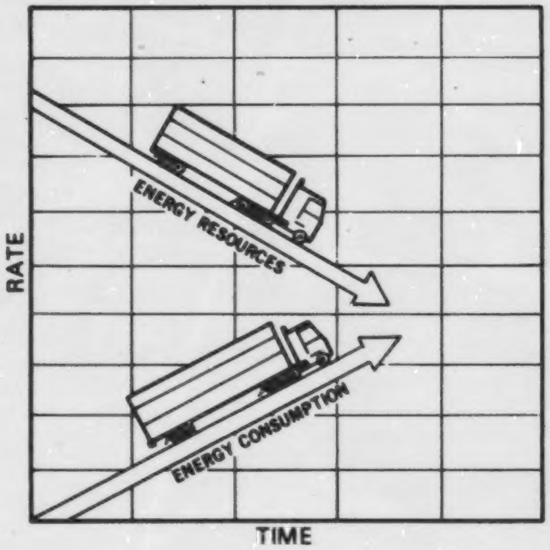

FIGURE 34. Energy consumption continues to increase while resources decrease.

This situation violates all rules of supply and demand. Certainly, it indicates a collision course, or a point of no return.

You have probably heard or read in recent years that doomsday is in sight for our supply of fossil fuels. Forecasting the end of our abundant energy era has been a popular topic among politicians, scientists, educators, the news media and the American public. Predicting the day, year or decade in which our fossil fuel supply will be exhausted is at present an impossible task.

Until recently, most of us thought that our fossil fuel sources were unlimited. Science and technology have proven us wrong. Now, more than in any other period in history, we are aware of the limited quantities of oil, coal and natural gas that lie below the earth's surface. We now know that these sources of energy that took Mother Nature over 100 million years to form are limited.

While the United States has only 6% of the world's population, it consumes 35% of the world's energy supply (Figure 35). As technology increases in other countries, it is expected that competition for the world's supply of energy will increase.

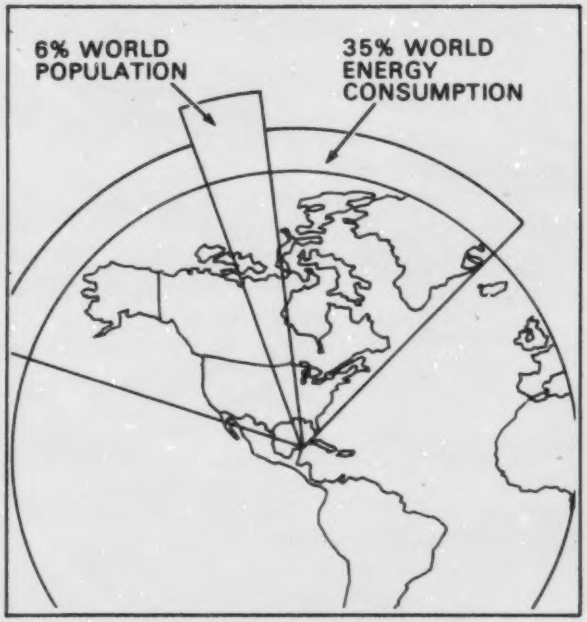

FIGURE 35. The U. S. has six percent of the world's population and uses 35 percent of the world's energy.

More than one third of the energy used in the United States is imported. A concerted effort is being made by both government and industry to reduce our dependence on foreign supplies. Some of the steps being taken are as follows:

- Increased use of coal.
- Increased oil exploration.
- Increased gas exploration.
- Developing alternate sources.
- Reducing waste.

As these programs develop, the rate of depletion will change. Perhaps it is not so important for an individual to try to predict how long supplies will last. But it is important to realize that fossil fuels are non-renewable resources and at the present consumption rate, they will be gone within a very few years. Perhaps not in your lifetime, but within a few generations. As supplies diminish, the cost will continue to increase.

Much effort is now being made by government and industry to change these rates of energy consumption. Thanks to the oil embargo of 1973, Americans, and people in other nations as well, experienced the effects of a fuel shortage. It was a reminder for people everywhere to take a serious look at the energy situation. They became more aware of the importance of energy in our daily lives.

Certainly there are many variables involved in projecting energy conservation. No one can precisely predict what conservation measures will take place and how effective they will be in perpetuating the life of our fossil fuels. One fact is certain: conservation of fossil fuels is imperative.

From your study of this section, you will be able to discuss different sources of fossil energy and their availability. They are discussed under the following headings:

1. Coal.
2. Oil.
3. Natural Gas.

1. COAL

Coal is the only non-renewable energy resource which still exists in relative abundance. Proven U. S. reserves are estimated to last up to 300 years at the current rate of use. Presently, about 65% of the coal mined is used for electrical generation; about 30% for industrial processes. In the future, it may be converted directly to gas or oil.

Although there are large reserves of coal in the Appalachians close to large markets, mining in Western states is expanding (Figure 36). Transportation to large markets will be more expensive. Ash disposal causes pollution. Combustion of high-sulfur coal releases sulfur dioxide. Western coal has less sulfur, but more ash, than Eastern coal. Underground mining is a hazardous operation. Stripmining—the easiest and least dangerous method—causes erosion and leaves barren wastes. Reclamation of surface-mined areas is expensive.

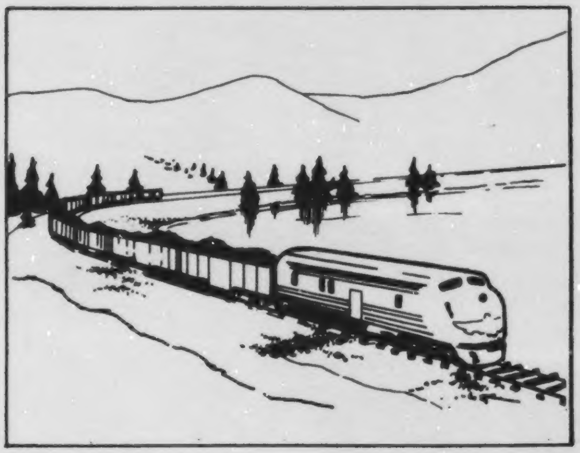

FIGURE 36. The supply of coal is still abundant in the United States.

Coal promises to have the greatest longevity of all of our fossil fuels. Estimates indicate that conservation measures might help supplies last well into the 22nd century.

2. OIL

The amount of oil which remains in the United States and offshore is unknown. One half our oil supplies now come from imports. Sixty percent is used for transportation (refined as gasoline and diesel fuel), 20% for residential/commercial heating, and 10% for electrical generation. Since domestic supplies are declining and foreign supplies are uncertain, we need to plan for less oil consumption in the future. Some estimates predict that oil supplies will last less than 100 years at our present rate of use. Exploration for additional oil reserves centers on sites under as much as 244m (800 ft) of ocean water and as far as 7,625m (25,000 ft) underground (Figure 37).

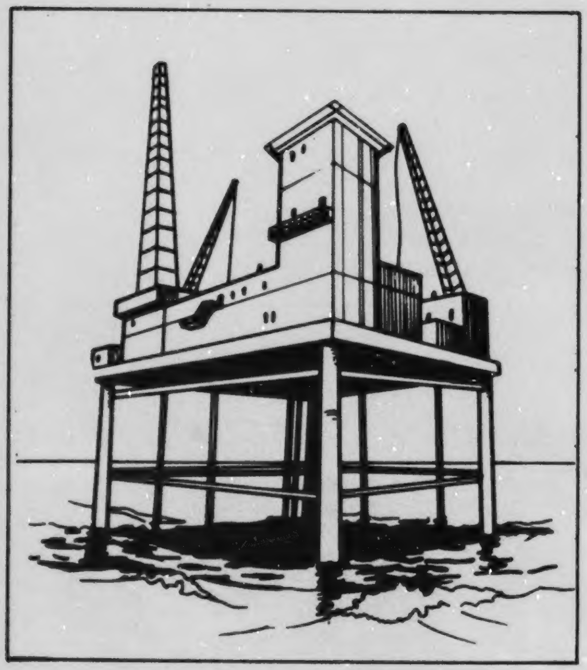

FIGURE 37. Exploration for oil under the ocean.

3. NATURAL GAS

The proven reserves of natural gas, at current use rates, would last only another ten years. Some gas is found with petroleum; some is found alone. Natural gas is treated to remove heavy hydrocarbons and hydrogen sulfide, which can be used by the petroleum and petrochemical industries. About 45% is used as industrial fuel, 35% for commercial/residential heating, and 10% for electrical generation.

At the present time, natural gas is our least expensive fossil fuel because of price controls that make it artificially cheap. With higher prices in the future, current users will need to switch to some other fuel. There will undoubtedly be opposition to such a switch since natural gas is the cleanest of the three fossil fuels and is in great demand for space heating.

B. What are the Prospects for Alternate Sources of Energy?

Much effort is being made toward developing alternate sources of energy. New sources are being explored. As the price of fossil fuels increases, it approaches the cost of alternate fuels. Then, more alternate fuels become marketable.

For the short term, our reliance for energy should seem to be on oil and gas. For the long term, we will be looking to coal, atomic power and solar. With large reserves in the United States, coal would appear to see us through the first quarter of the next century. For any lasting relief, we must hope that practical means can be found to tap solar radiation, winds, tides, and geothermal sources on a larger scale. In the immediate future, the hope for alleviating shortages lies with reducing demand.

Figure 38 shows the share of total U. S. energy supply that each major source provided in the recent past with projections for the near future.

From your study of this section, you will be able to list some alternate sources of energy and explain their importance. They are discussed as follows:

1. NUCLEAR

Nuclear energy may be the major new source of energy for the next few years (Figure 39). Nuclear energy is used primarily to heat water and make steam which turns steam turbine generators. Restrictions on its use may change the projections, however.

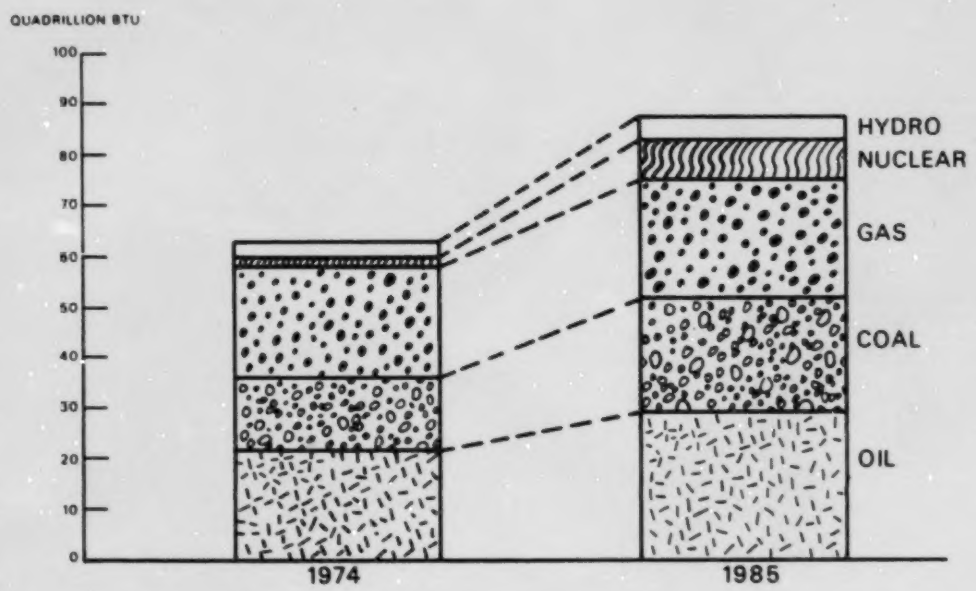

FIGURE 38. Projected use of domestic supply of current major energy resources (National Energy Outlook, DOE, 1976).

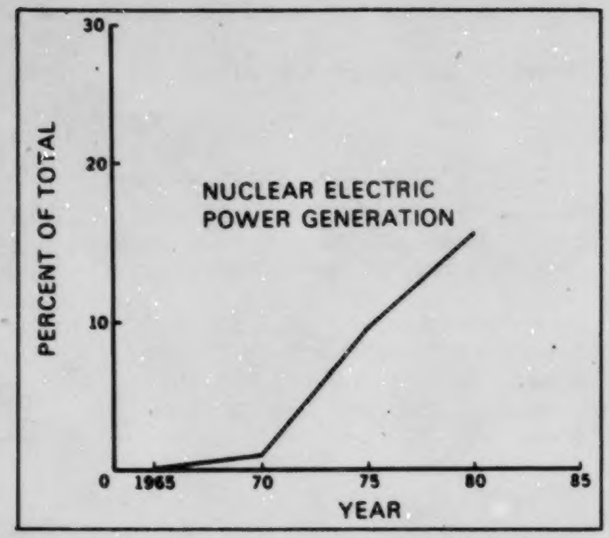

FIGURE 39. An estimated projection of the use of nuclear energy for power generation (National Energy Outlook, DOE, 1976).

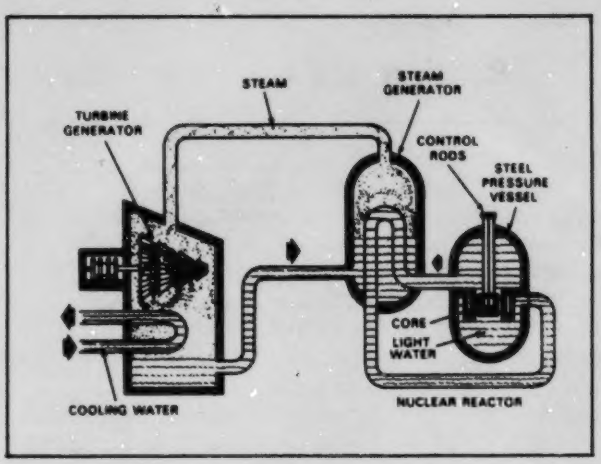

FIGURE 40. Cross sectional sketch of a nuclear-powered steam generator.

The source of nuclear energy is also limited. In the United States, it is estimated that there is about a 20- to 50-year supply of uranium. Uranium is used in the present electrical power plants. It is a fissionable material.

Uranium, as a fuel for nuclear reactors, is a controversial energy source. Its advantage lies in the fact that 28 gm (1 oz) of U^{235} has a heat value equal to 388 barrels of petroleum. Mining uranium is a great deal more difficult than mining fossil fuels, however. Even the richest uranium ore may contain only a fraction of one percent of uranium. Because uranium ore is not pure and the costs of extraction vary, the amount of current reserves is hard to estimate. Some say we have about a 30 year's supply left of U^{235}-- the uranium necessary to produce fission reactions in conventional nuclear power plants. The drawbacks to fission as it is presently used to produce electricity are the radioactive wastes, possible accidents which would release radiation into surrounding areas, and thermal pollution resulting from the large amounts of water from lakes and rivers required for cooling.

Resources for the other type of nuclear energy, fusion, are unlimited. Lithium hydride, a source of deuterium and tritrium, is abundant. This process has not been harnessed as yet. It takes 180,000°F to set off a fusion process and this amount of heat is difficult to contain.

2. SOLAR

The potential use of solar energy is vast. Proper design can be used to take advantage of solar heat. In passive solar heating, the sun's energy enters a building, is sometimes stored for later use, and heats the building without the use of fans, pump, or other mechanical devices. The warmth moves by natural means—conduction, convection and radiation. Passive solar systems are more likely to be suitable for new construction than for modification of existing buildings.

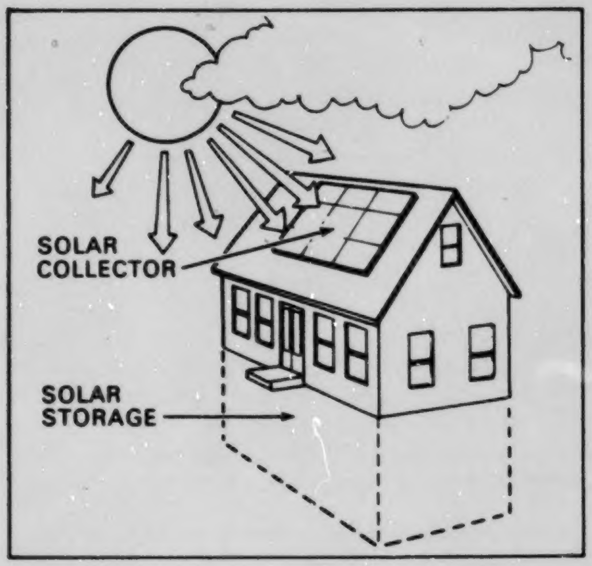

FIGURE 41. The sun's energy is collected and stored for use as needed.

Presently, there are some very promising approaches to using solar energy for low temperature needs such as water heating and space heating (Figure 41). Although the first cost for these systems is relatively high, in most parts of the country, these systems are expected to be cost-effective, especially as the cost of other energy sources rises. The National Solar Heating and Cooling Information Center (P. O. Box 1607, Rockville, MD 20850) is a good source of free up-to-date information on uses of solar energy. Call toll free (800) 523-2929; in Pennsylvania (800) 462-4983; in Alaska and Hawaii (800) 523-4700.

By the year 2000, solar heating and cooling could satisfy perhaps half the needs of all new residential and commercial buildings. An advantage of solar energy is that it is an immense energy source with few adverse environmental effects. There is plenty of solar radiation on the earth's surface (Figure 42). But to be useful, practical, efficient and economical, ways must be employed to capture, store and redistribute that energy as needed. This is the challenge of the growing solar industry.

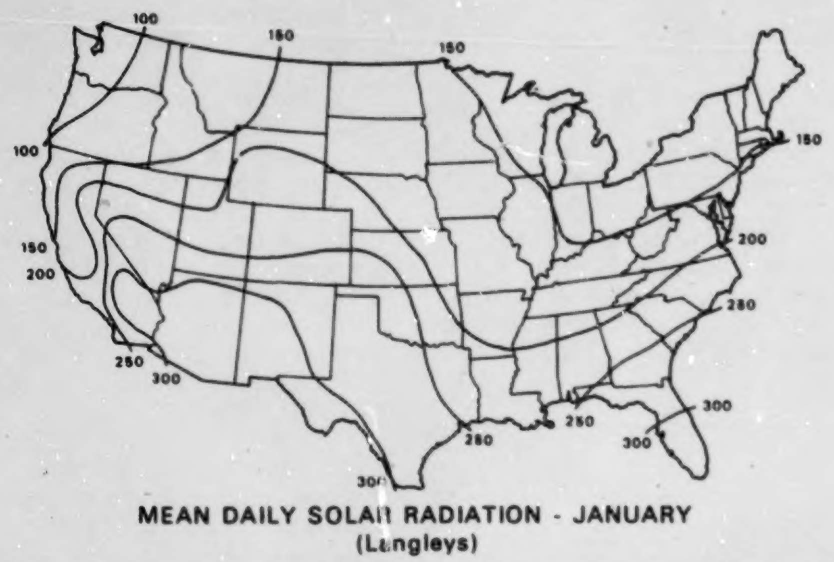

FIGURE 42. Total daily solar energy at the ground in July (Calories/square centimeter) (Solar Energy, DOE, 1976).

3. PHOTOVOLTAIC CELLS

Photovoltaic cells are silicon crystals that convert solar energy directly into electrical energy (Figure 43). An optimistic view is expressed by scientists for less expensive and more efficient cells to be developed. At present, however, they are costly and operate at about 18% efficiency.

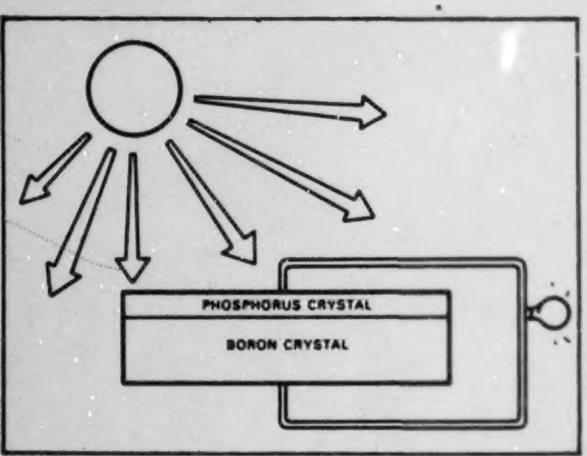

FIGURE 43. Photovoltaic cell.

4. HYDRO

Water power, or hydroelectric potential, in the United States is already close to full development and environmental problems will probably prevent many additional sites (Figure 44).

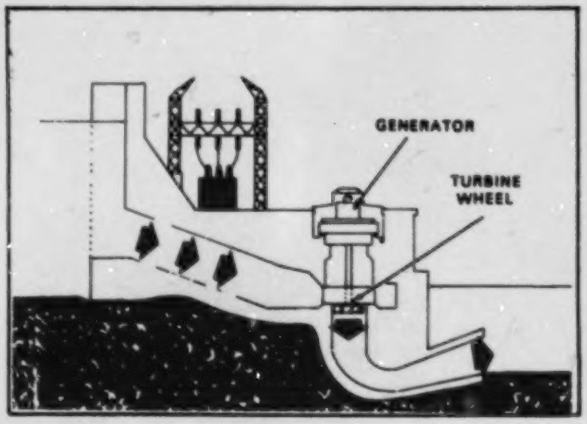

FIGURE 44. Principle of a water-powered generator.

Increased use of hydroelectric power will be in the form of pumped storage systems which will use the space capacity of "base load" electric plants (for example, in the middle of the night) to provide power during periods of peak demand the next day. Water will be pumped uphill for storage, and power will be produced later when it is released downhill (Figure 45).

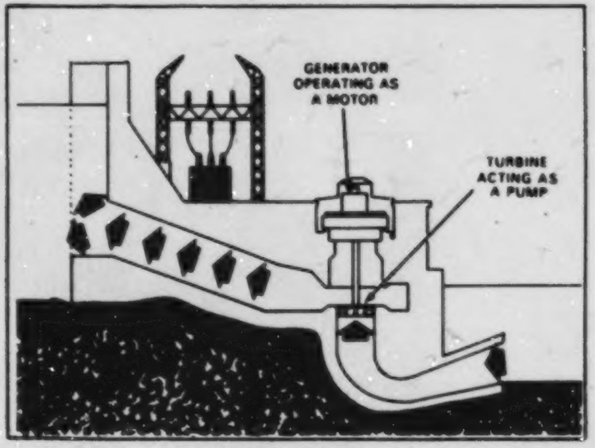

FIGURE 45. A pumped storage system.

5. SOLID WASTE

Solid municipal waste is being used to a very limited extent as fuel to operate steam-powered generators (Figure 46). A few plants are in use that provide as much as 20% of a city's electricity from the solid waste.

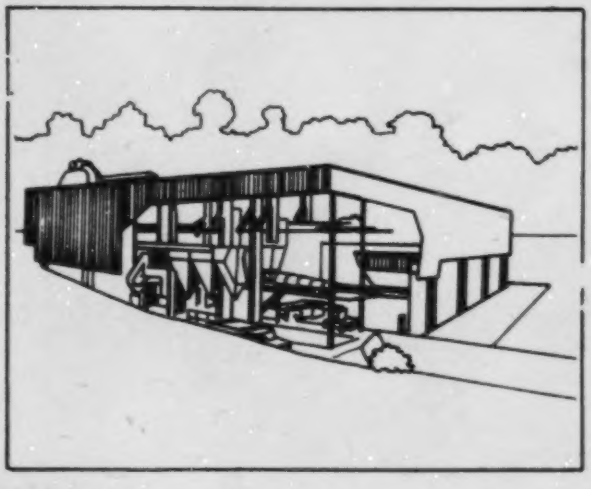

FIGURE 46. Electric power plant using solid waste fuel.

Burning combustible trash, in mixture with coal or other fuel, to power electric generators is becoming an attractive idea. In fact, some small plants are already in operation converting solid wastes to electrical power. A cheap, readily available fuel, conventional combustible garbage possesses 50% of the potential heat of coal. Although the waste disposal problem is solved, the air pollution problem remains. If we took full advantage of the energy contained in all refuse, a small percentage of our energy needs would be met.

6. SYNTHETIC FUELS

Waste sewage and other carbohydrates are all being used to make combustible liquids such as methanol and alcohol. Methanol has a good potential for fuel in automobile engines (Figure 47). It may be mixed with gasoline or used directly. Some forms of algae produce hydrocarbon as a by-product. Production is limited and expensive.

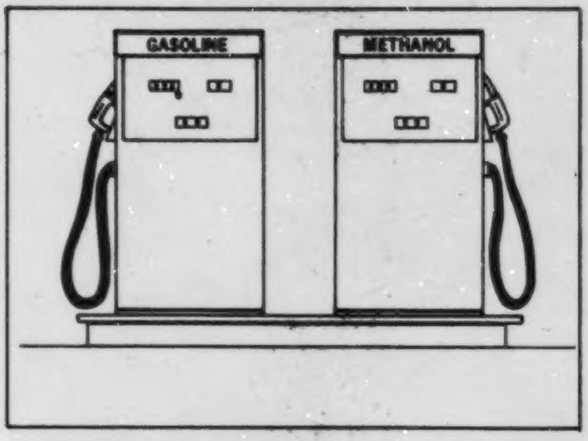

FIGURE 47. Methanol may be used in automobiles.

The processing of organic matter and waste through decomposition produces a gas called methane. Methane, unlike fossil gases, can be created in a matter of weeks under controlled conditions. The way in which methane is used determines its potential for pollution. When stored, then processed in a fuel set-up, the waste by-product is fresh water which is non-polluting.

7. WIND

Wind energy was popular in the early days of the country to pump water. But with the advent of electricity, its conversion and low cost, windmills lost their appeal (Figure 48). There is some potential for wind generation of electric energy, perhaps eventually as much as 10% of the total need (Figure 49). The amount varies in different parts of the country (Figure 50). The potential for wind energy is third after solar and photovoltaic sources.

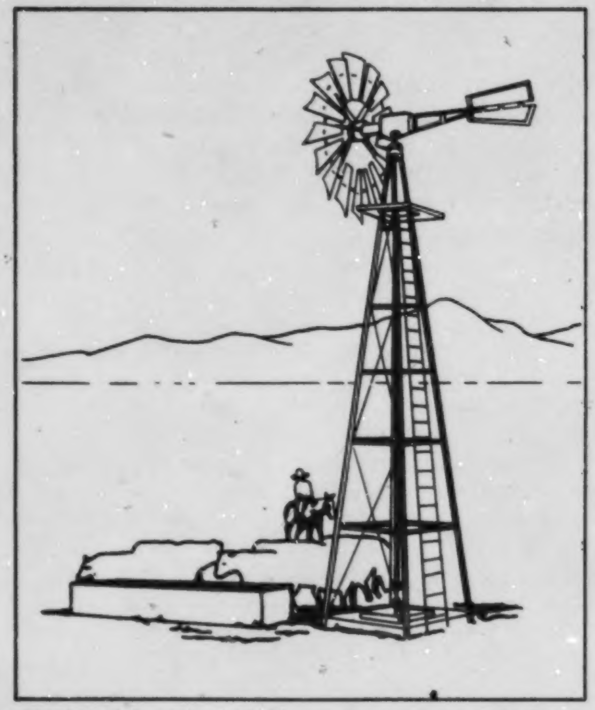

FIGURE 48. Windmills once were used for grinding grain and pumping water.

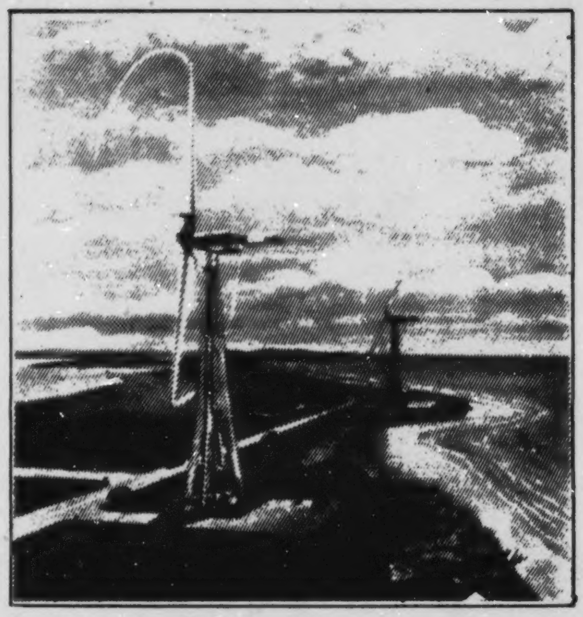

FIGURE 49. Wind generator.

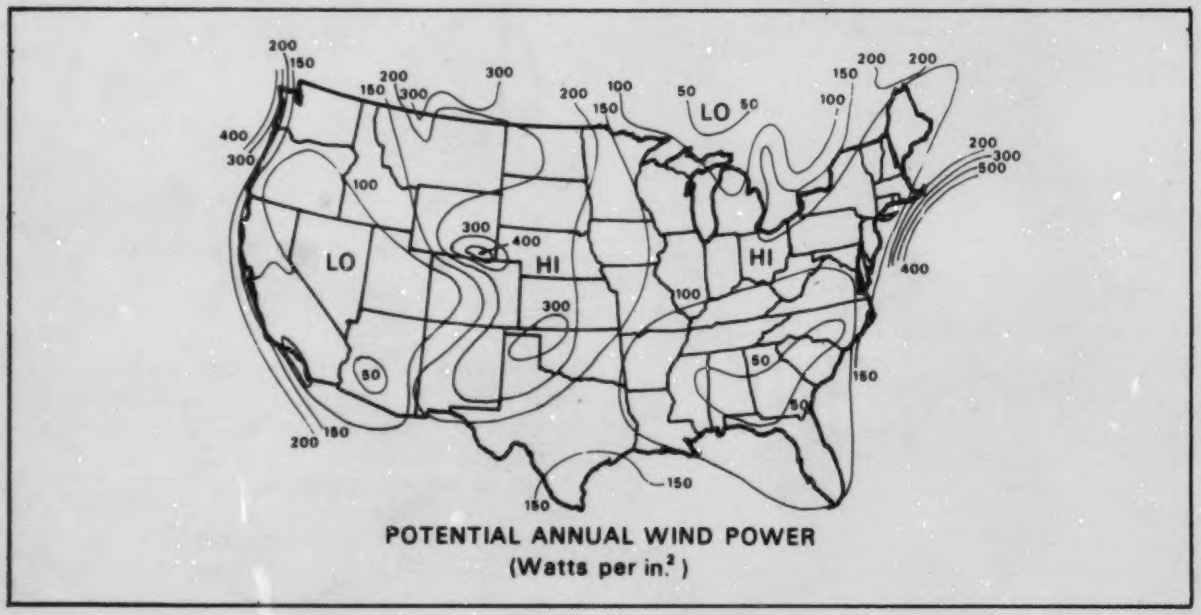

FIGURE 50. Relative wind capacities in the United States (Solar Energy, ERDA, 1976).

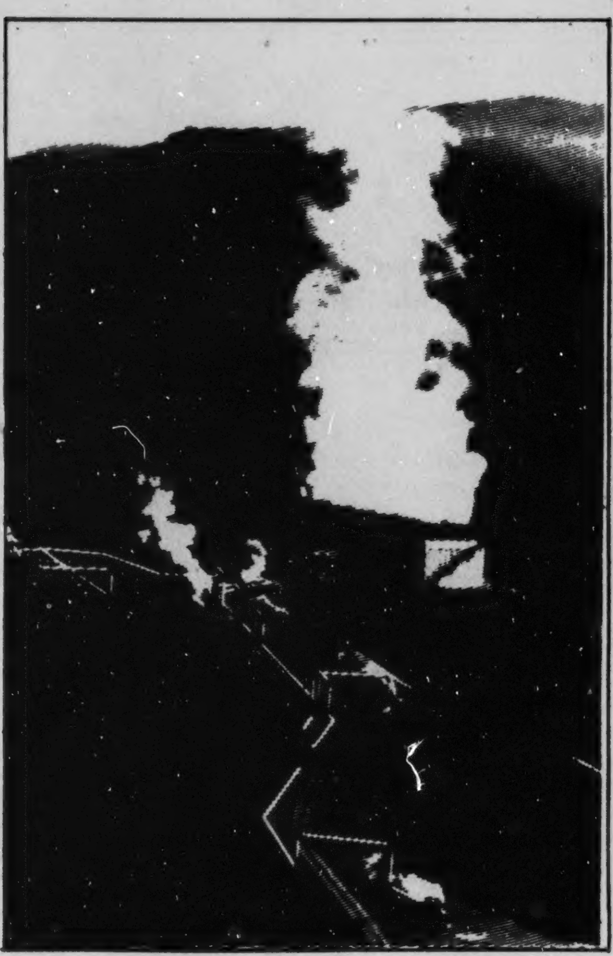

FIGURE 51. Geothermal steam field and power plant.

8. GEOTHERMAL

All natural geyser areas of the world are potential sites for geothermal energy (Figure 51). Geothermal energy is stored under the earth's surface in the form of heat. This energy source is limited in its distribution and will not supply a large portion of our needs (Figure 52).

Large amounts of geothermal energy (heat in the form of steam, such as that found in geysers) are present in the earth's crust, but it is possible to tap these resources only in limited locations. California has the most promising sites developed to date. Experts feel that over the next 25 years as much as 25,000 MW will be provided by geothermal plants, where steam from the earth is used to drive turbines which generate electricity. It will provide limited, local energy to a few favorable locations but cannot contribute a great deal to our national energy budget.

9. TIDES AND OCEAN TEMPERATURES

The ocean tide and temperature variations in ocean water have also been considered as potential sources for energy (Figure 53). This source seems to be very limited, but some plants are being built.

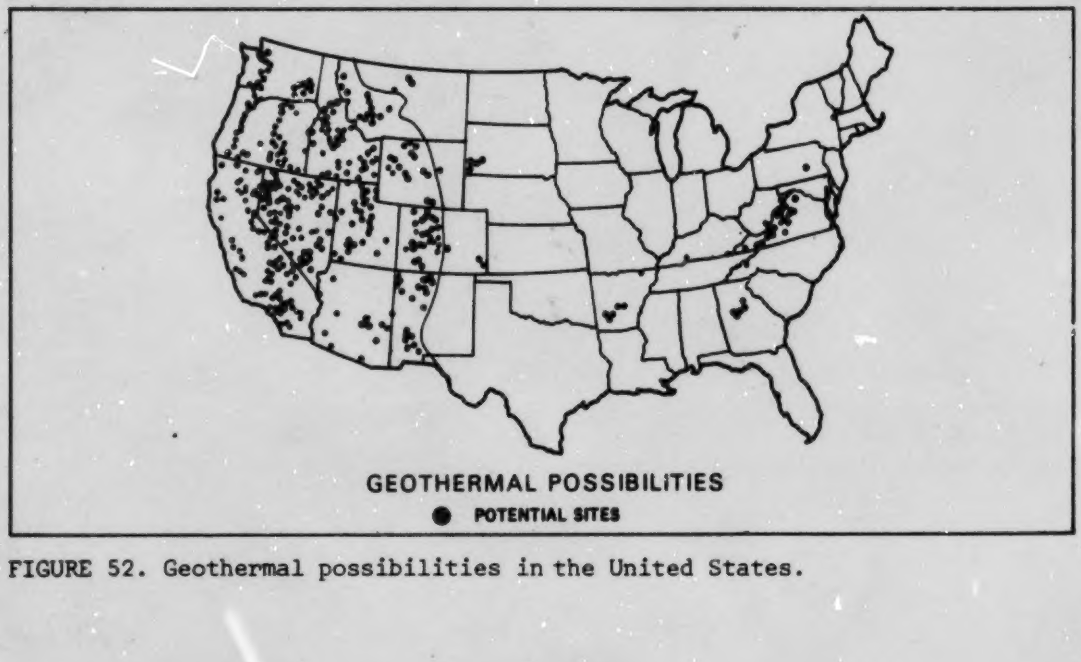

FIGURE 52. Geothermal possibilities in the United States.

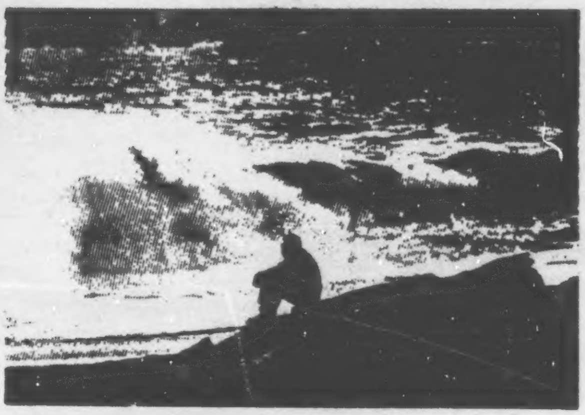

FIGURE 53. The ocean tide is a potential source of energy.

The differential ocean temperatures may also be used for generating electricity in offshore power plants.

10. WOOD

Wood is still an important energy source, provided it is grown as a crop under good management (Figure 54). However, growing forests in new areas would face competition for land use by the agricultural sector.

FIGURE 54. Wood is an important source of energy.

11. SHALE OIL

Shale oil is sedimentary rock from which oil can be extracted by heat. Some experts estimate that the United States has more oil in this form than all of Saudi Arabia's proven oil reserves. With present technology, this form of energy extraction is costly in comparison to conventional petroleum. As the price of conventional petroleum escalates, so does the feasibility of shale oil recovery. A tremendous amount of water is required and environmental problems are involved.

C. What Effect May the Energy Situation Have on an Individual?

From this section, you will be able to discuss some of the effects that energy shortages may have on individuals. They are as follows:

1. Effect of Cost.
2. Effect on the Economy.
3. Effect on Lifestyle.

1. EFFECT OF COST

Already the cost of energy is increasing. All the alternate systems cost more than existing systems. The further development of new sources of coal, oil and gas is going to be more expensive than it has been in the past.

Coal is coming from more remote areas. Ecological standards are high. Land must be reclaimed where strip mining is used. Exploration for oil and natural gas in offshore operations is expensive. Test holes are made now where there are only slight possibilities of oil and gas.

Reclaiming oil from shale is an expensive process.

The cost of foreign oil has increased three times in the last four years. The use of alternate sources is usually more expensive than conventional sources.

Best estimates are that energy prices will continue to increase by about 10% per year. Cost of heating and cooling buildings will continue to increase. As the cost of energy increases, people must establish new priorities. A greater percentage of pay checks will be spent for energy (Figure 55). As this expense gets too burdensome, conservation measures will take place by necessity rather than by choice.

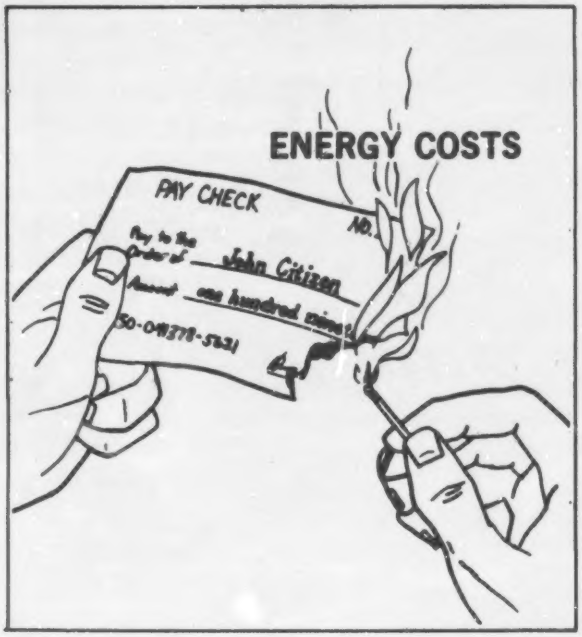

FIGURE 55. More of individual incomes will be used for energy.

Costs of all forms of transportation will rise, thus making it desirable for people to live near their jobs, schools, churches and recreation centers. Use of public transportation systems will increase as the cost of owning and maintaining a private vehicle rises.

2. EFFECT ON THE ECONOMY

A real problem with the present energy situation is that the United States is spending more for foreign oil than it gets back in foreign trade. This deficit in the balance of payments causes unemployment and upsets the economy.

The rate of about 45 billion and more per year for foreign oil leaves many American dollars overseas (Figure 56).

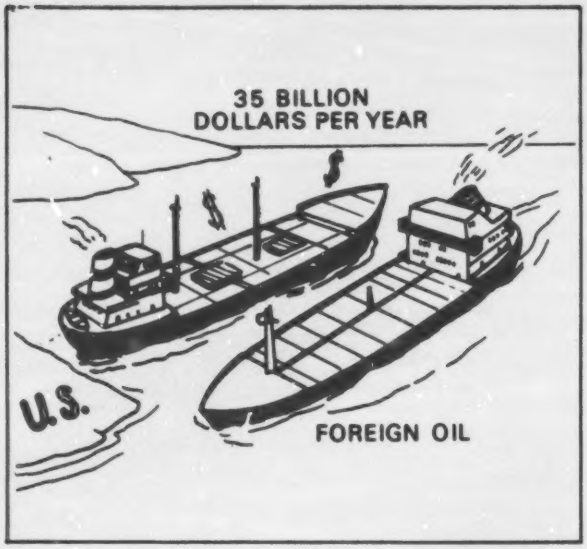

FIGURE 56. The U. S. exchanges 45 billion dollars per year for foreign oil.

The picture is not all bleak. In spite of the high cost of energy, the Department of Energy expects an increase in consumption by about 2% per year. It is believed that by conservation and increased efficiency in the use of energy that a 3% annual growth rate of the gross national product could be achieved.

What can an individual do? Conserve energy. Reduce waste. Eliminate unnecessary use of energy in your transportation, in your business and in your home and other buildings.

3. EFFECT ON LIFESTYLE

Much effort is being made toward maintaining the lifestyle to which everyone is accustomed. Health comes first but a lot of energy can be saved without impairing your health. A little discomfort from being too warm or too cool will not affect your health. While saving energy may cause a little inconvenience, it will not hurt you.

There is a trend toward smaller automobiles, mass transportation and reduced travel. In buildings, the emphasis is on reducing the heat loss and gain and changing the thermostat settings. Thermostats are turned down in winter and up in summer.

People are considering smaller houses and they are reducing the amount of space heated and cooled. But so far, no drastic changes have taken place in lifestyles (Figure 57). As the cost and availability of energy increase, the change will become more drastic.

FIGURE 57. Few people have changed lifestyles because of the energy shortage.

III. Understanding the Use of Energy in Buildings

Energy requirements for heating and cooling buildings are measured in joules (Btu). For example, the heating requirements for a home during one season may be as much as 106 to 212 billion joules (100 to 200 million Btu).

The term for measuring energy is the joule [British Thermal Unit (Btu)]. A Btu is the amount of heat required to raise 454 g (1 lb) of water 0.56°C (1° F). This quantity is equivalent to the burning of a wooden match. The three primary sources of heat in buildings are natural gas, oil and electricity. Energy available from each is as follows:

Natural Gas - 39.2 MJ/m^3 (1,052 Btu/ft^3)
Oil - 38.5 MJ/l (138,000 Btu/gal)
Electricity - 3.6 MJ/kW.h (3,410 Btu/kW.h)

The efficiency of gas and oil is about 75%. When the equipment is new, the efficiency of electricity is 100%. But the conversion of gas and oil to electric energy is 35% efficient.

It is estimated that 38% of the energy consumed in the United States is used in buildings--24% in residences and 14% in commercial buildings.

Without reducing comfort and convenience appreciably, certain measures may be taken that will save as much as 2/3 of this amount. Such a saving would result in a 10% decrease in the total consumption, or 7.8 quintillion joules (7.4 quadrillion Btu)--the equivalent of 3 1/2 million barrels of oil per day.

How energy is used in buildings is discussed under the following headings:

A. How Energy is Used in Buildings.
B. How Geographic Locations Affect Energy Use in Buildings.
C. How Design and Construction Methods Affect Energy Use.
D. General Recommendations for Energy Efficiency in Buildings.

A. How Energy is Used in Buildings

Most of the energy used in buildings is for space heating (Figure 58). It ranges from 60% to 75% depending on the climate. In colder climates, more energy is needed for space heating. Water heating is the next single largest use of energy. In the warm sections of the country, air conditioning is a big factor. Lighting amounts to only about 2 percent.

You can see that the first places to look for savings are in space heating, water heating and other appliances. Of course, if you live in a hot climate, air conditioning will be more significant.

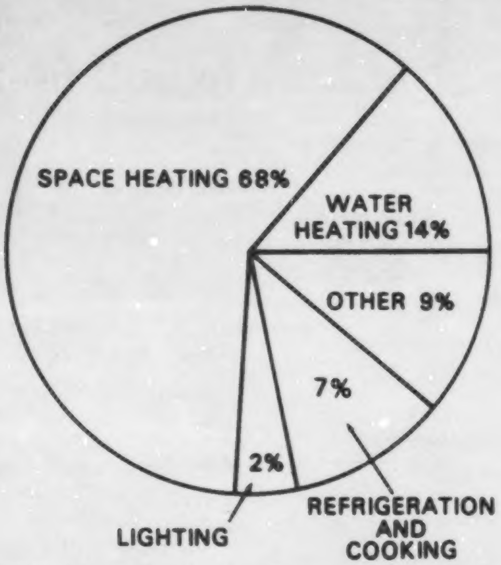

FIGURE 58. Estimate of average distribution of energy in U. S. homes, DOE, 1977.

Since equipment and appliances differ from building to building, it is hard to estimate the energy usage. A large percentage of commercial equipment must be warmed up before it will operate efficiently. As a result, many office and factory machines are turned on early in the morning and are in operation all day whether they are being used or not. One classic example is the coffee percolator which is used in almost all commercial buildings. Duplicating and copy machines are on most of the time.

In large buildings, escalators and elevators are standard equipment. The escalator is another machine that consumes energy whether it is being used or not. An average 0.8 m (32 in) wide escalator, operating at 27.5 m/mu (90 ft per min), with a 4.3 m (14 ft) vertical rise, will use 4.68 MJ (1.3 kWh) per hour. An average 2,043 kg (4,500 lb) elevator, stopping on 12 floors, will take up 8.1 kWh per car-kilometer (13 kWhr per car-mile), so these machines do consume large amounts of energy.

Commercial buildings and residences consume one-third of all the energy used in this country. Energy is used in heating and cooling the building. It is used in lighting, appliances and equipment and is required to make plumbing function properly.

From your study of this section, you will be able to describe how energy is used in buildings. It is discussed under the following headings:

1. Heating.
2. Cooling.
3. Plumbing and Water Heating.
4. Lighting.
5. Appliances and Equipment.

1. HEATING

Heating consumes about 68% of all energy used in buildings (Figure 59).

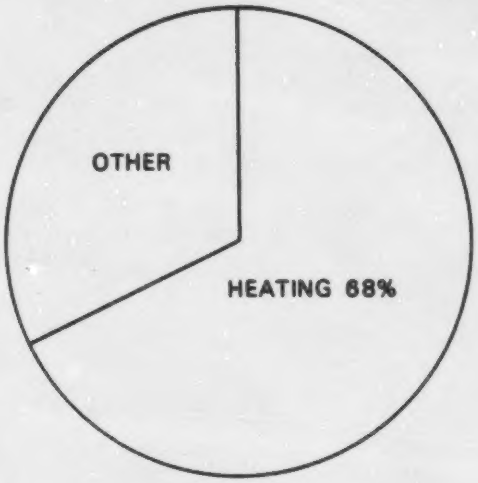

FIGURE 59. Most of the energy used for buildings is for space heating.

For space heating, fuels are consumed in mechanical equipment to provide heat (Figure 60).

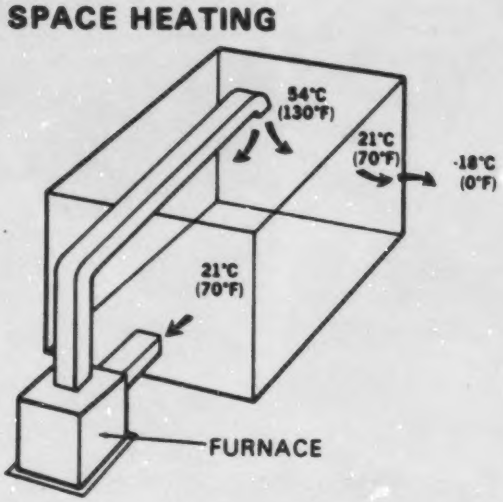

FIGURE 60. Space heating is accomplished by burning fuels in mechanical equipment.

Such units include forced air furnaces, open coil units, heat pumps and closed hot water or steam systems, to mention only a few. Despite the vast differences in heating systems available, most of them use three types of energy, gas, oil and electricity.

2. COOLING

Space heating and cooling are called "space conditioning." Cooling consumes less than 5% of energy used in homes (Figure 61) in the United States. Unlike heating units, cooling units generally use electricity as a power source. Even though there are two main types of air conditioners, compressive refrigeration and absorption, both use electricity to function. The object of air conditioning is to maintain a comfortable temperature inside the house when the outside air temperature is uncomfortably hot (Figure 62). The operating efficiencies of air conditioning systems vary considerably. Commercial buildings use about 9% for air conditioning.

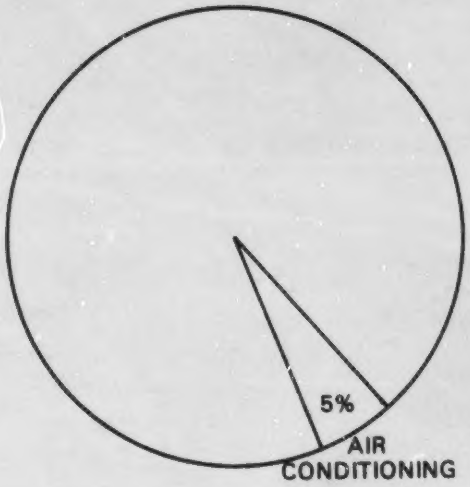

FIGURE 61. Energy used for cooling is about 5% of the total in homes.

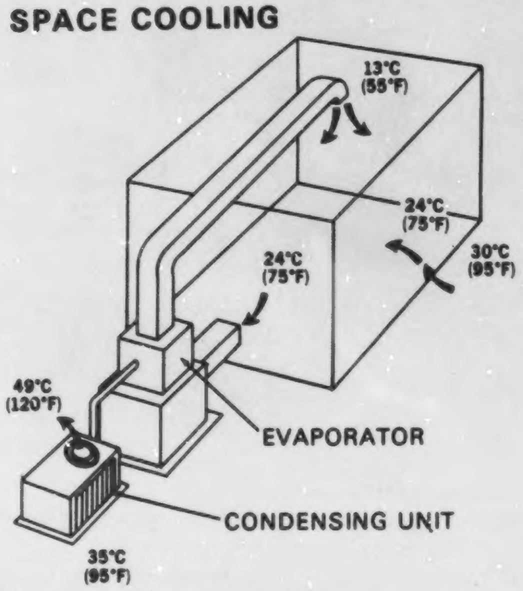

FIGURE 62. Air conditioning requires energy to lower the temperature inside buildings.

3. PLUMBING AND WATER HEATING

Except for heating water, plumbing is probably the most energy-free convenience that we have. Most water supply systems are already under pressure when the water arrives from city water mains. Pumps are required to increase water pressure in multi-story buildings and to supply water directly from wells.

The design and size of water heaters vary, but the principle of heating water is basically the same in all systems (Figure 63). An average home for a family of four with about 160 m^2 (1800 ft^2) will use approximately 15 million Btu's per year for heating hot water.

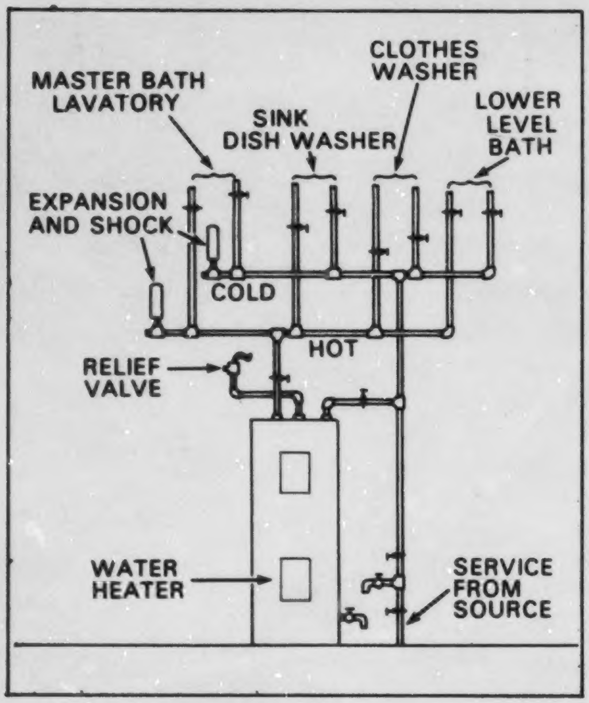

FIGURE 63. Conventional hot and cold water systems.

4. LIGHTING

Lighting uses about 2.0% of all electricity consumed in the home (Figure 64). There are three major types of artificial lighting: incandescent, fluorescent and H.I.D. (high intensity discharge). All of these use electricity as their source of power, some more than others (Table I).

Incandescent lamps produce light by heating a tungsten filament with an electrical current until it emits light. The filament is encased in an evacuated glass tube to prevent rapid disintegration. These lamps are least efficient for giving off light.

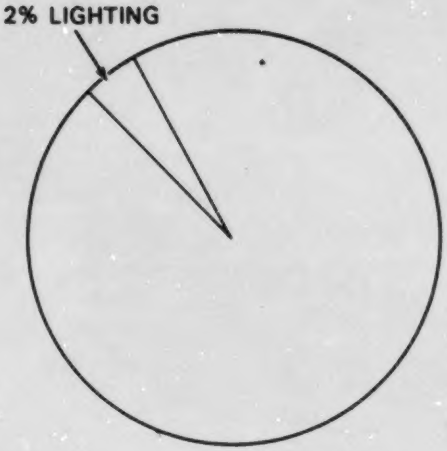

FIGURE 64. Lighting uses about 2% of energy in homes.

Fluorescent lamps produce light by the flow of electrical current through inert gases. These gases emit ultraviolet radiation which is absorbed by the fluorescent powders that coat the inside of each lamp. They are much more efficient for giving off light than incandescent lamps.

H.I.D. lamps are similar to fluorescent lamps with the exception that the light is emitted directly by the inert gas. Mercury-vapor is enclosed in a quartz bulb and visible light is given off when an electrical current flows through the bulb. A second bulb surrounds the first and filters out the unwanted radiation and light. H.I.D. lamps are slightly more efficient than fluorescent.

TABLE I. COMPARISON OF EFFICIENCIES OF THREE TYPES OF ELECTRIC LAMPS*

Type of Lamp	Lumens/Watt
Incandescent	8-26
Fluorescent	30-83
HID (sodium)	74-132

*Lighting, DOE, 1978.

5. APPLIANCES AND EQUIPMENT

Appliances use about 9% of the energy in homes (Figure 65). Gadgets and appliances operate from either one of two primary energy sources, electricity and natural gas. Electricity is by far the most common source of power.

Relative amounts of energy consumed by appliances and other mechanical conveniences are given in Tables II and III.

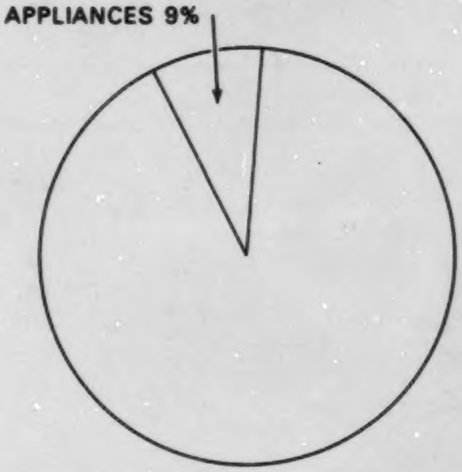

FIGURE 65. Appliances use about 9% of energy in homes.

TABLE II. ENERGY CONSUMPTION OF MAJOR APPLIANCES*

Major Appliances	kWh/yr
Air-Conditioner (room) (Based on 1000 hours of operation per year. This figure will vary widely depending on geographic area and specific size of unit)	860
Clothes Dryer	993
Dishwasher (including energy used to heat water)	2,100
dishwasher only	363
Freezer (0.45 M^3) (16 ft^3)	1,190
Freezer--frostless (0.46 M^3) (16.5 ft^3)	1,820
Range with oven	700
with self-cleaning oven	730
Refrigerator (0.33 M^3) (12 ft^3)	728
Refrigerator--frostless (0.33 M^3) (12 ft^3)	1,217
Refrigerator/Freezer (0.35 M^3) (12.5 ft^3)	1,500
Refrigerator/Freezer (frostless) (0.49 M^3) (17.5 ft^3)	2,250
Washing Machine--automatic (including energy used to heat water)	2,500
washing machine only	103
Washing Machine--non-automatic (including energy to heat water)	2,497
washing machine only	76
Water Heater	4,811

*Tips for Energy Savers, DOE, 1977.

TABLE III. ENERGY CONSUMPTION OF PORTABLE APPLIANCES*

Kitchen Appliances	kWh/yr
Blender	15
Broiler	100
Carving Knife	8
Coffee Maker	140
Deep Fryer	83
Egg Cooker	14
Frying Pan	186
Hot Plate	90
Mixer	13
Oven, Microwave (only)	190
Roaster	205
Sandwich Grill	33
Toaster	39
Trash Compactor	50
Waffle Iron	22
Waste Disposer	30

Housewares	kWh/yr
Clock	17
Floor Polisher	15
Sewing Machine	11
Vacuum Cleaner	46

Home Entertainment	kWh/yr
Radio	86
Radio/Record Player	109
Television	
Black & white	
Tube type	350
Solid state	120
Color	
Tube type	660
Solid state	440

Heating and Cooling	kWh/yr
Air Cleaner	216
Electric Blanket	147
Dehumidifier	377
Fan (attic)	291
Fan (circulating)	43
Fan (rollaway)	138
Fan (window)	170
Heater (portable)	176
Heating Pad	10
Humidifier	163

Laundry	kWh/yr
Iron (hand)	144

Health & Beauty	kWh/yr
Germicidal Lamp	141
Hair Dryer	14
Heat Lamp (infrared)	13
Shaver	1.8
Sun Lamp	16
Toothbrush	0.5
Vibrator	2

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*Tips for Energy Savers, DOE, 1977.

NOTE: When using these figures for projections, such factors as the size of the specific appliance, the geographic area of use, and individual use should be taken into consideration.

B. How Geographic Locations Affect Energy Use in Buildings

Energy requirements of buildings vary with the geographic location. For example, in cold locations more energy is required for heating (Figure 66). For example, it takes three times as much fuel to heat a house in New York as it does the same type of house in Georgia (Table IV).

TABLE IV. COMPARISON OF ENERGY REQUIREMENTS TO HEAT SIMILAR HOUSES IN FOUR DIFFERENT CLIMATIC ZONES

Bismark	New York	Denver	Atlanta
	Billion Joules		
528	211	148	72
	Million Btu		
500	200	140	67

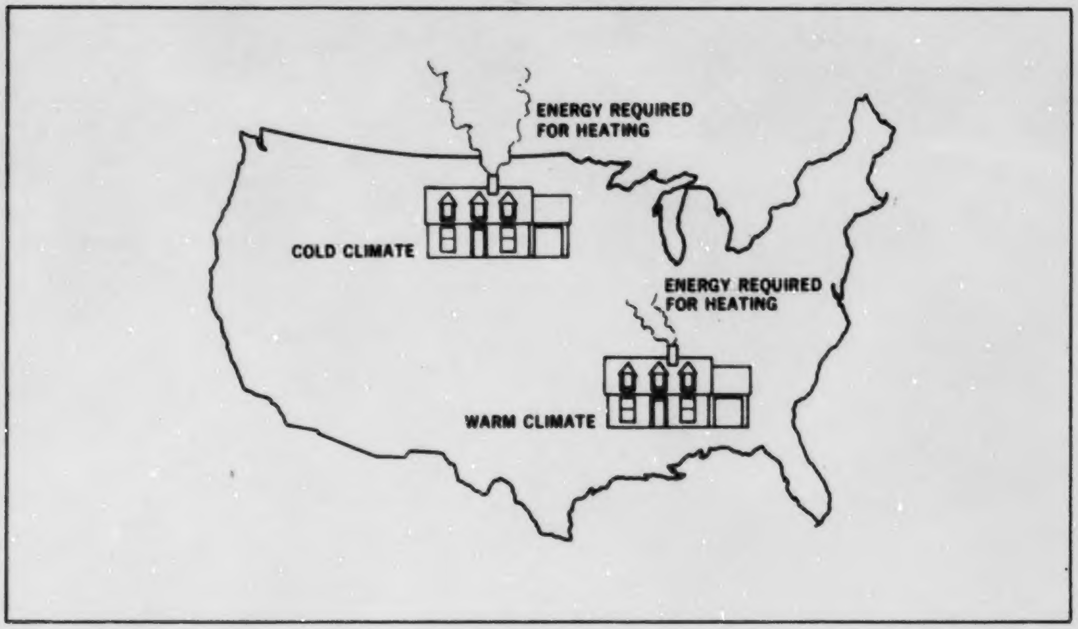

FIGURE 66. In cold climates, more energy is required for heating than in warm climates.

The United States is divided into four geographical zones for design purposes (Figure 67). With the addition of Alaska and Hawaii, two more zones are added.

Table V gives climatic conditions that influence energy use in buildings.

From your study of this section, you will be able to explain how geographic location affects energy use in buildings.

Four factors are involved. They are discussed under the following headings:

1. Temperature.
2. Moisture.
3. Wind.
4. Sun.

TABLE V. CLIMATIC CONDITIONS THAT INFLUENCE ENERGY USE IN BUILDINGS

Location	Temperature Winter	Temperature Summer	Moisture	Wind	Sun (Annual Hours)
N. Ohio	Cold	Hot	Humid	Windy	2200
N. Minnesota	Cold	Hot	Humid	Windy	2200
Oregon	Mild	Mild	Wet	Moderate	1800
N. Mississippi	Cold	Hot	Humid	Windy	2600
Gulf Coast	Cool	Hot	Humid	Moderate	2600
S. Florida	Warm	Hot	Humid	Moderate	2800
Colorado	Cold	Mild	Dry	Windy	3600
S. West	Mild	Hot	Dry	Windy	4000

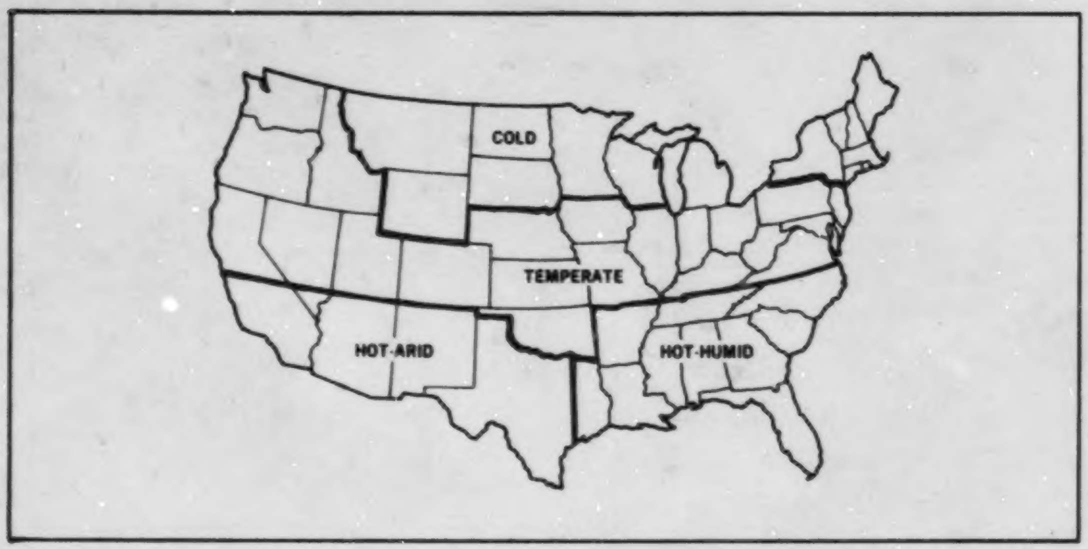

FIGURE 67. Climatic regions in the United States.

1. TEMPERATURE

Temperature is the most important factor in energy use in buildings. As you know, the winter temperature is maintained in most buildings at 20°C (68°F) to 21°C (70°F). When the temperature outside is lower than 18°C (65°F), energy is required to raise the temperature inside the building (Figure 68).

Inside temperature is maintained at 26°C (78°F) during the summer. When the outside temperature is greater than this, energy is required to lower the temperature inside (Figure 68). The energy required in both instances is to maintain a 6°C (22°F) difference in temperature.

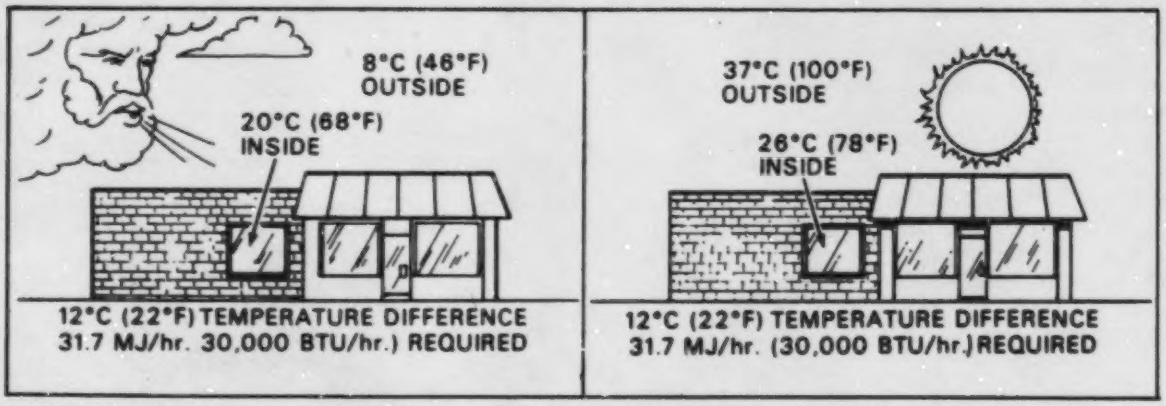
8°C (46°F)
OUTSIDE
20°C (68°F)
INSIDE
12°C (22°F) TEMPERATURE DIFFERENCE
31.7 MJ/hr. 30,000 BTU/hr.) REQUIRED
37°C (100°F)
OUTSIDE
26°C (78°F)
INSIDE
12°C (22°F) TEMPERATURE DIFFERENCE
31.7 MJ/hr. (30,000 BTU/hr.) REQUIRED

FIGURE 68. Energy is required to maintain the temperature within a building at a comfortable level.

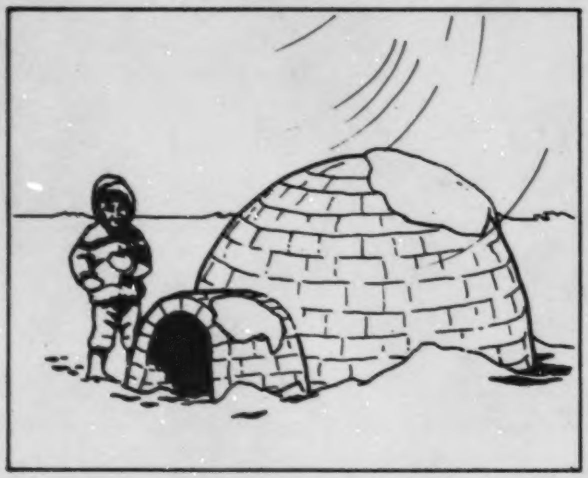

FIGURE 69. Ice-constructed igloos insulate against cold.

Early settlers of this continent built for environmental comfort without using extensive amounts of energy. In cool regions, snow provided thermal insulation as it enclosed space. The smooth, interior ice lining sealed against outside air infiltration and loss of inside heat (Figure 69). Animal skins draped on the inside surface of igloos reduced radiant heat loss from occupants.

In hot-arid regions the thick adobe construction used for roof and wall constructions delayed the impact of solar radiation until late in the day (Figure 70). Adobe construction also retained heat for a long period of time, thus providing warmth during cold evenings. Small openings, such as doors and windows, minimized direct transmission of solar radiation and hot air. Shelters were oriented in a north-south direction to minimize the impact of a hot, rising sun or an even hotter setting sun.

2. MOISTURE

The relative humidity is important in designing housing. Chill factors are partially determined by the amount of moisture in the air. Most people are comfortable at 40-60% relative humidity. Relative humidity is the amount of moisture in the air compared to the amount that could be there. You are more comfortable when the air is dry and cold than when it is damp and cold (Figure 72).

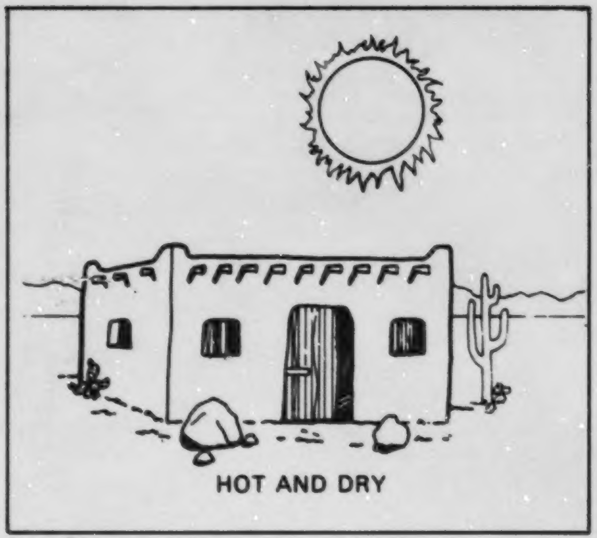

FIGURE 70. Adobe construction protects against heat.

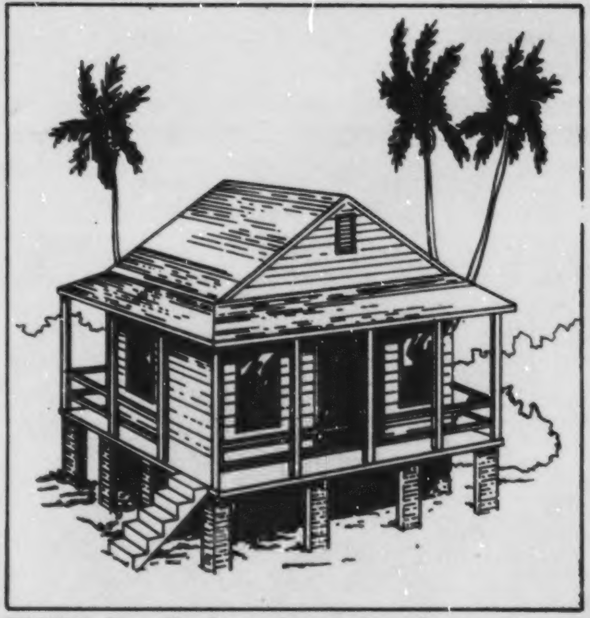

FIGURE 71. Shade and ventilation protect from heat in hot-humid regions.

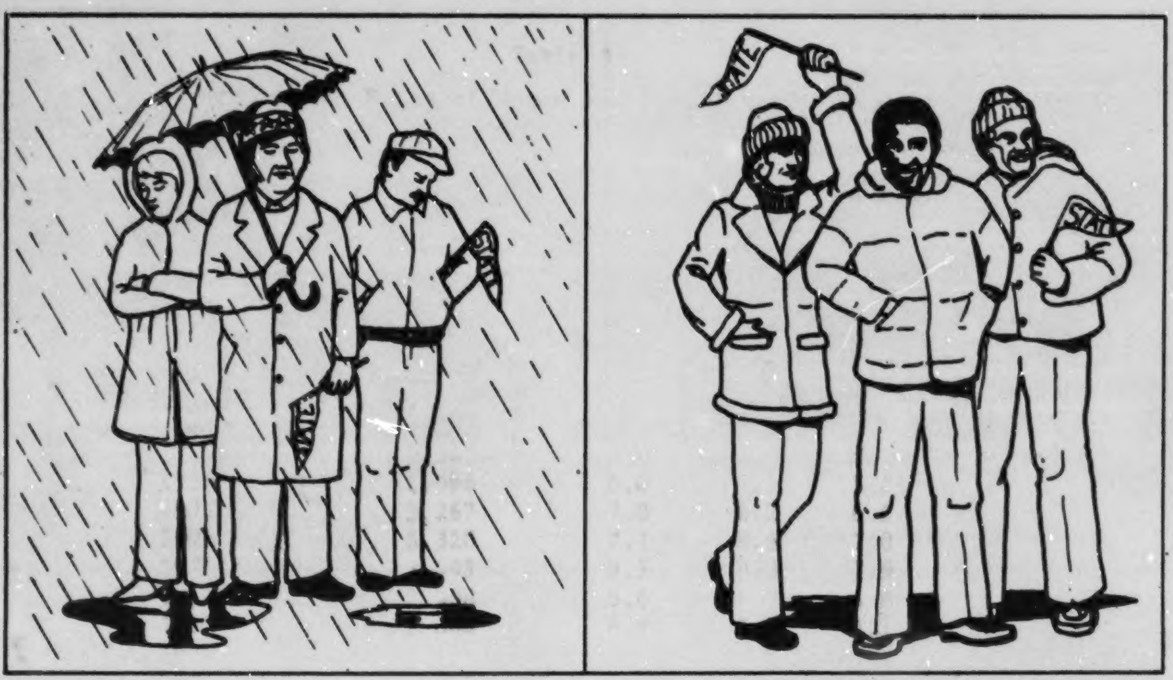

FIGURE 72. Damp and cold are more uncomfortable than dry and cold.

In hot-humid regions, overhangs provide shade on the structure to reduce solar radiation (Figure 71). Breezes are desirable so open walls and elevated floors allow air circulation for cooling by natural ventilation.

If your building is damp, a higher temperature is needed for comfort, thus more energy is required.

Also, you are more comfortable when the air is dry and hot than when it is moist and hot.

3. WIND

The wind is also a factor in energy use in homes. Where practical, your house should be protected against cold prevailing winds (Figure 73). Infiltration of cold air through cracks and crevices increases energy use considerably. A house without caulking and weatherstripping may use twice as much energy as one with caulking and weatherstripping.

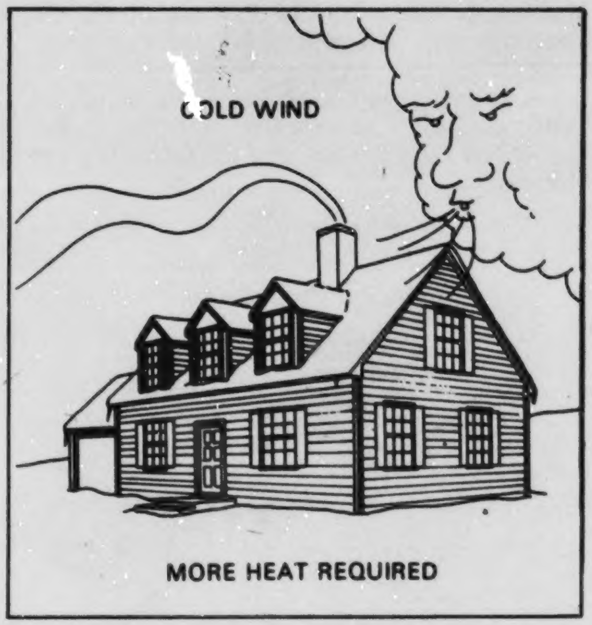

FIGURE 73. Cold winds increase the use of energy in buildings.

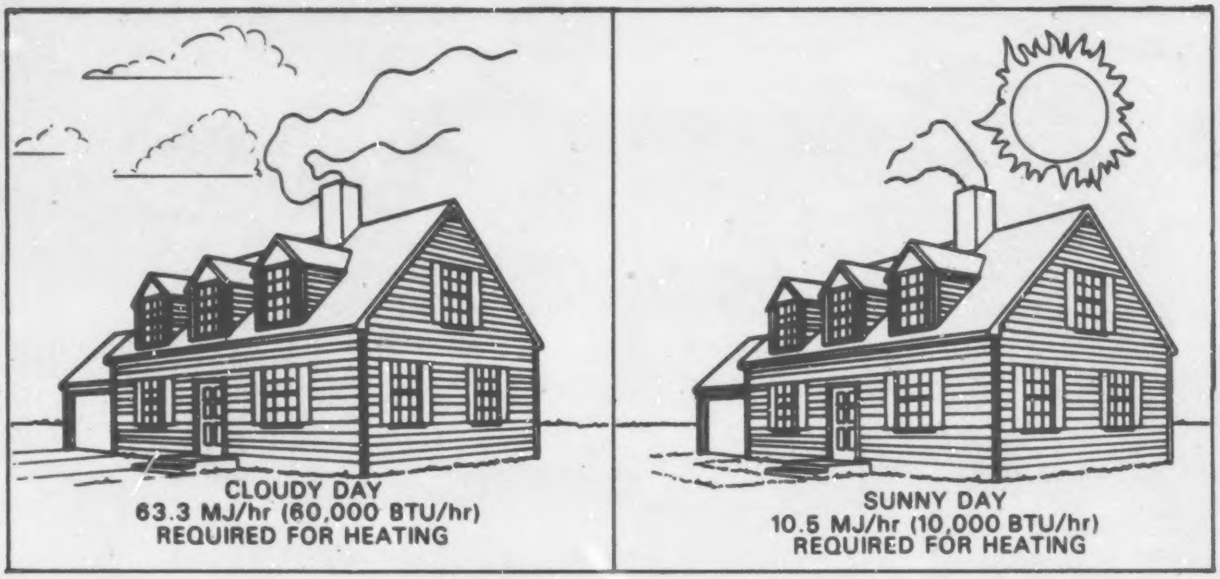

FIGURE 75. More energy is required for heating on a cloudy day than on a sunny day.

On the other hand, a breeze can be quite welcome in the summer. The desire to utilize nature's air conditioning probably inspired the innovation of the porch. The old possum run or dog trot houses in the south provide comfort by channeling prevailing summer breezes (Figure 74). Air conditioning systems have not duplicated the effect of a fresh breeze.

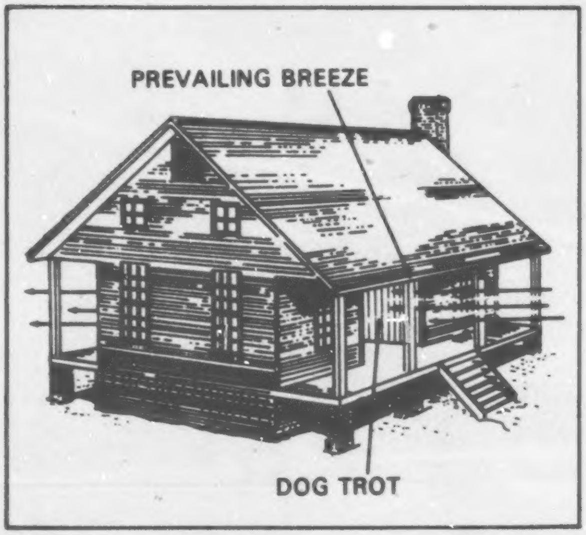

FIGURE 74. Porches and breezeways help cool houses.

Long ago, farmers who lived close to nature learned things about the wind that we should utilize. They learned that trees can divert the wind's direction. Farmers built their houses and animal shelters down wind of and adjacent to windbreaks. Claims are made that when houses are placed in these wind-shield areas, as much as 20% of fuel cost is saved.

4. SUN

Sunshine aids in reducing energy needs for buildings (Figure 75). On the other hand, it increases the need for cooling. There are certain parts of the country that have more sunshine than others. Usually, these are in the warmer climates.

The sun is high in summer, low in winter. The sun's path is precise and predictable (Figure 76). Designers use this fact as an opportunity to control the sun's effect on energy use in buildings.

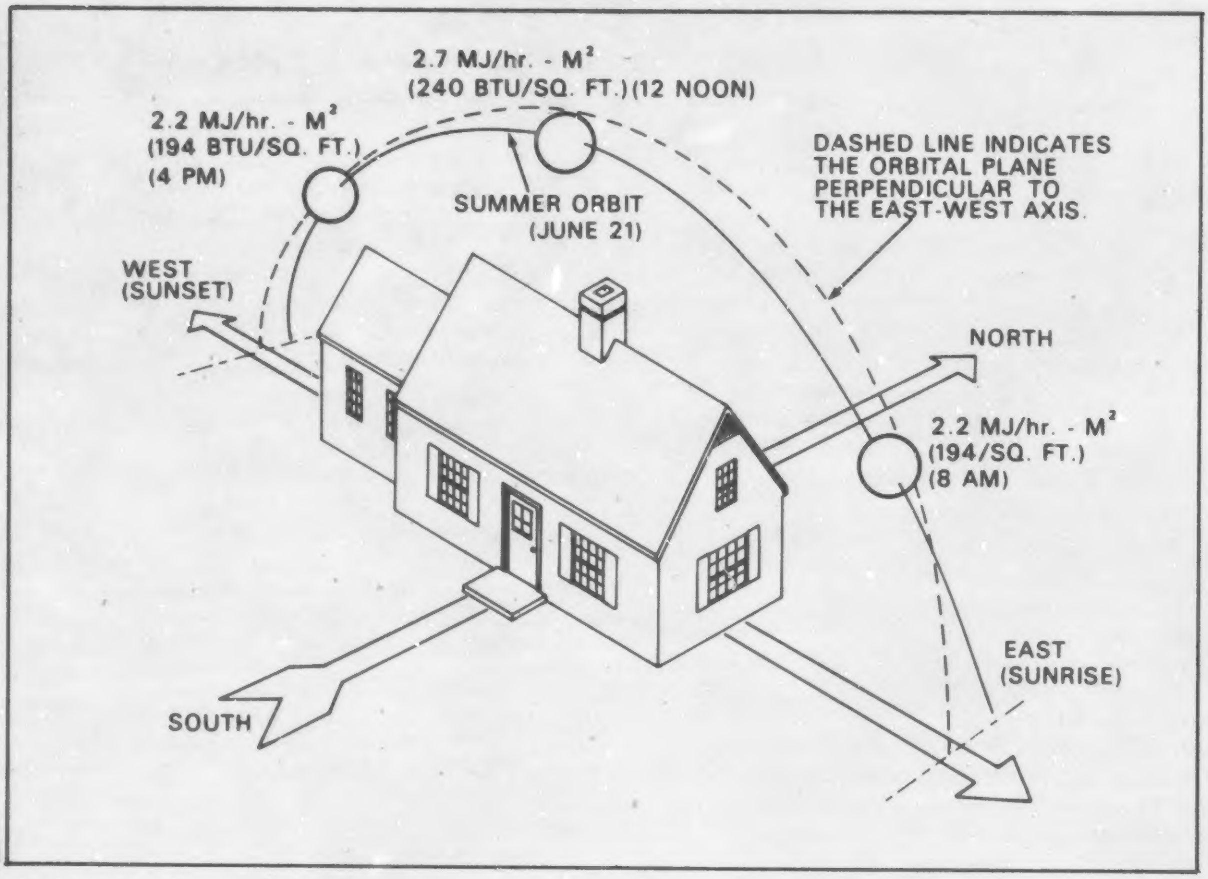

FIGURE 76. The path of the sun influences the use of energy in buildings.

C. How Design and Construction Methods Affect Energy Use

Several factors influence the amount of energy used in buildings.

Planning an energy-efficient home or building begins with the selection of the site, followed by the proper orientation of the building on the site. Design of the structure, arrangement of rooms, selection of materials and mechanical equipment are of equal importance in an energy-efficient building. Your understanding of design and construction methods will help you save energy in your building.

From this section you will be able to describe how design and construction methods affect energy use. They are discussed under the following headings:

1. Effect of Site Location.
2. Effect of Design.
3. Effect of Materials Used.
4. Effect of Insulation.
5. Effect of Vapor Barriers.
6. Effect of Weatherstripping and Caulking.
7. Effect of Windows and Doors.
8. Effect of Heating Methods.
9. Effect of Air Conditioning.
10. Effect of Ventilation Method.
11. New Methods of Heating and Cooling.
12. Effect of Lighting.
13. Effect of Plumbing.
14. Energy-Efficient Appliances.

1. EFFECT OF SITE LOCATION

Site location and the orientation of buildings on the site affect the amount of energy used in heating and cooling. The sun and wind are two major factors that influence energy use.

Keep in mind that in the northern hemisphere the sun is high in the sky during the summer and lower on the horizon during the winter.

Hill tops, ridges and higher elevations have more exposure to the wind and are colder in the winter and cooler in the summer. In cold climates, select southern exposures protected by land of higher elevations. Flat sites are open to full sweeps of wind. Air temperatures near large bodies of water are tempered by the wind.

Some trees make good wind screens. Deciduous trees are excellent summer shelters, while evergreens provide shelter the year round.

Room orientation is also important. Rooms of major use oriented to the southern, warmer side of a building capitalize on solar energy.

Energy consumption can be reduced by choosing the site carefully. Site location should vary, depending on the climatic zone. Site locations should be considered for each of the zones as follows:

a. Cold Zone

A house built on the northern or western slope with little or no protection from the prevailing winds will use more energy than one situated on the southern or eastern slope (Figure 77).

Vegetative protection can also be a factor in energy use.

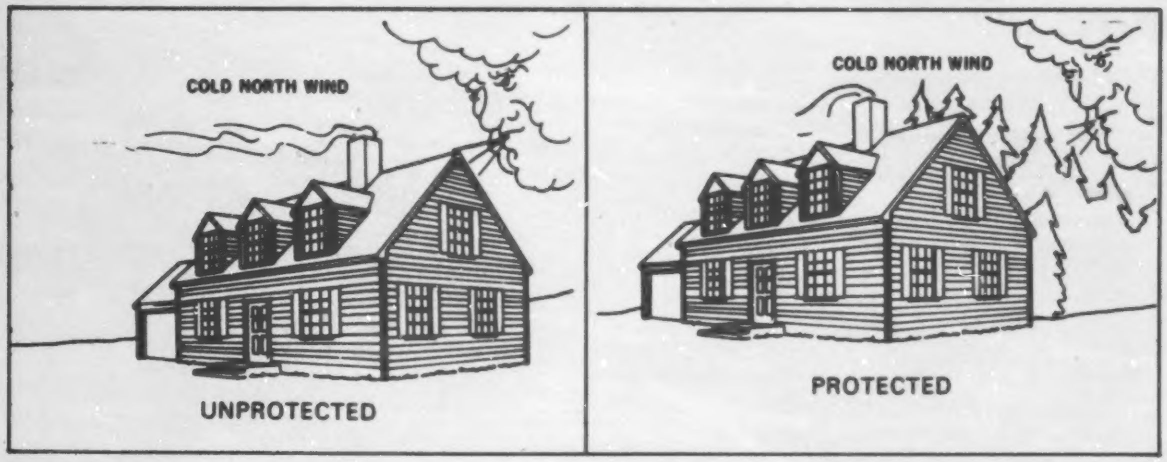

FIGURE 77. Buildings exposed to cold prevailing winds will use more energy for heating than those protected.

b. Temperate Zone

A balance is needed in the temperate zone between protection from wind in winter and access to air in summer. Also, vegetative protection that is used in winter may be used as shade in summer (Figure 78).

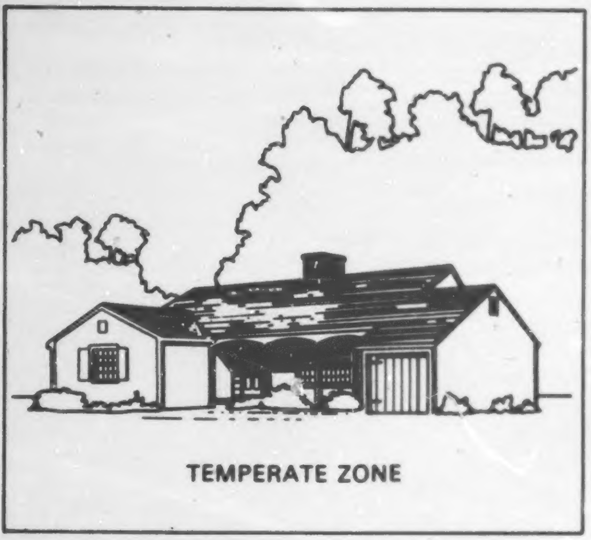

FIGURE 78. A building in the temperate zone should be moderately protected.

c. Hot-Humid Zone

Summer comfort is more important than winter heat in the hot-humid zone. If air circulation is inadequate during summer, excessive energy will be needed for cooling. Houses should be situated on southern and northern slopes with vegetative protection and shade provided (Figure 79).

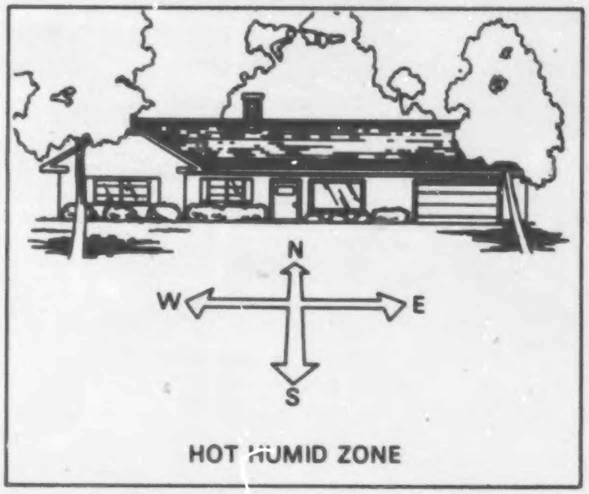

FIGURE 79. Buildings in the hot-humid zone should be oriented toward the north or south with ample shade for summer.

d. Hot-Arid Zone

Houses should be oriented toward the east with afternoon shading (Figure 80). Wind is not important here because it is generally not too cold in winter and it is hot and dry in summer. It is best if you can shield the building from summer prevailing winds.

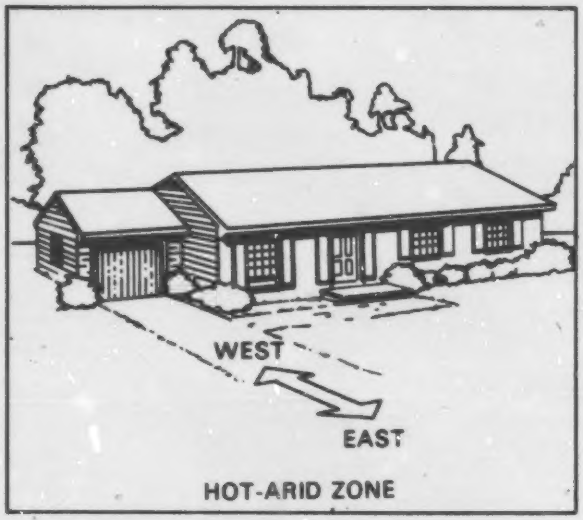

FIGURE 80. Buildings in the arid west should face the east and utilize afternoon shading whenever possible.

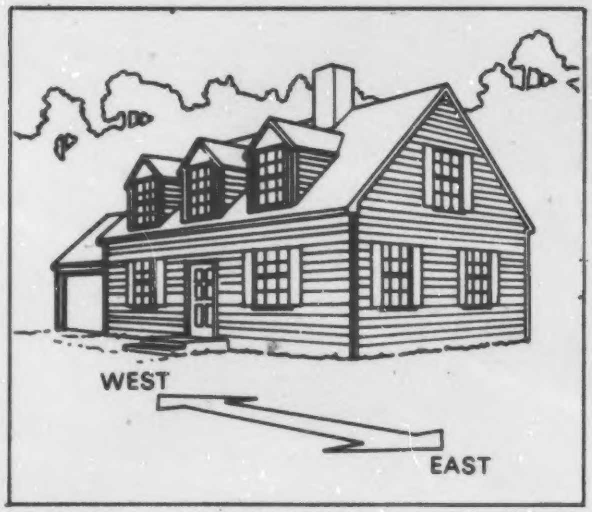

FIGURE 81. Rectangular houses oriented toward east and west generally use less energy year round.

2. EFFECT OF DESIGN

The shape of a building also has an effect on the amount of energy used. Generally, a rectangular house oriented east and west will use the least amount of energy (Figure 81).

Design should allow for exposure of windows to sun in winter and shade in summer (Figure 82). Shades may be used effectively.

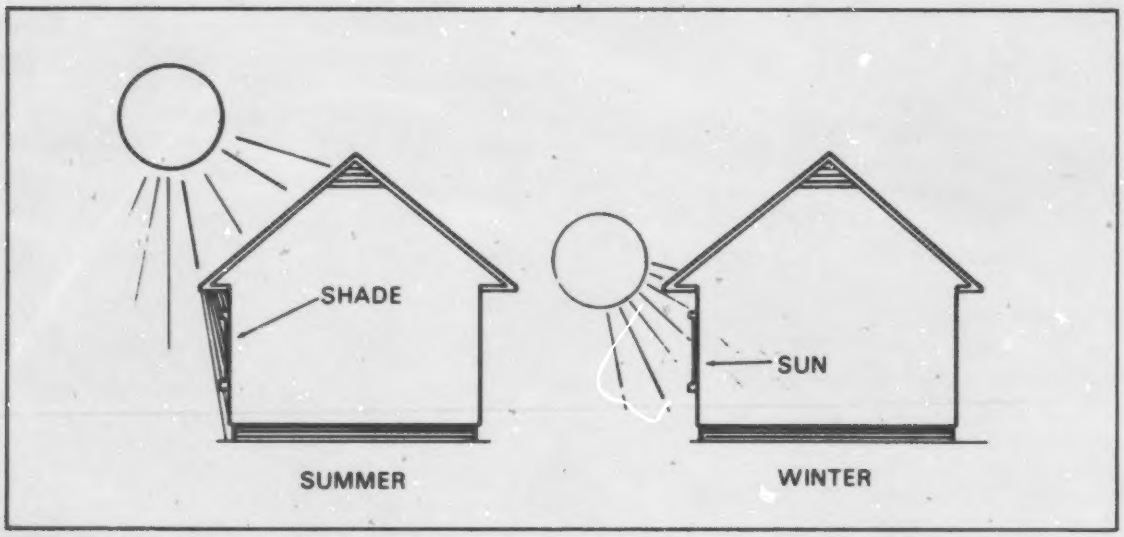

FIGURE 82. Windows should be exposed to sun in winter and should be shaded during summer.

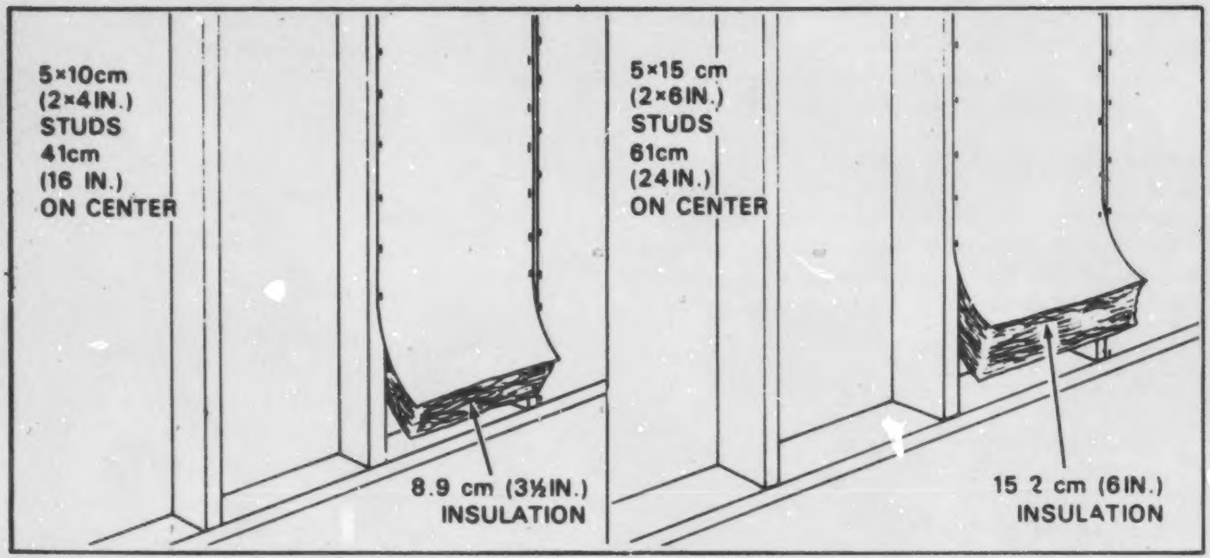

FIGURE 84. Structures may be designed to accommodate more insulation.

Designers are changing their philosophy about buildings. The "anything goes" attitude which was characteristic of the past decade has suddenly evolved into a functional and efficient approach to building design. For example, rambling structures are being replaced with cubicle buildings which have a minimum of exterior surface area. Such measures cut down on one of the greatest sources of heat loss.

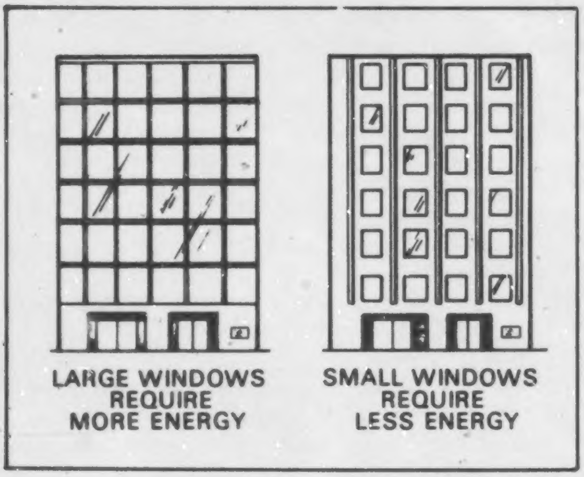

FIGURE 83. Large windows require more energy than small windows.

The use of glass has become an important factor in design. Before energy conservation was important, designs with large expanses of uninsulated and unprotected glass were common. Now the amount of glass used in many building designs is being reduced (Figure 83). Nearly everywhere in the continental United States, south-facing windows admit more heat than they lose. To effectively reduce heat loss through windows, at least two layers of glass are needed in cold climates. A third layer of glass, or movable insulation (curtains or shutters) covering the glass at night, can reduce heat loss further. An overhang or other shading will cut unwanted summer heat.

Designs are being adopted which utilize better insulation. A new design innovation is the Arkansas System which recommends 5.1 x 15.2 cm (2 x 6 in) stud framing to accommodate more insulation (Figure 84).

Additional conservation measures include the utilization of insulated doors and multi-pane windows. General, overhead lighting fixtures are being replaced by task lighting.

Many factors are taken into consideration, including the orientation of the house, slope of the roof, hours of sunshine, prevailing winds and site latitude.

Mechanical equipment should not impose large loads on the utility system during peak periods. The selection of oversized equipment should be avoided. In commercial buildings, the most significant features include the use of insulation, proper fenestration, control of ventilation, levels of illumination, orientation of the building, and the exposed surface area.

It has been proven that construction costs do not have to be greatly affected in either residential or commercial buildings in order to save energy. An example of this fact in commercial buildings is in the General Service Administration Building in New England. Energy usage is cut between 30-50% by the use of good design. The price came to $50.10 per square foot in comparison with the average cost of $50.00 per square foot for similar construction in that area.

3. EFFECT OF MATERIALS USED

In order to conserve energy in buildings, the principle is to reduce heat transfer through the outer structure of the house. Some building materials allow more heat transfer than others. For example, just as much heat will be lost, or gained, through the same area of 20.3 cm (8 in) of concrete block as through 1.9 cm (3/4 in) of wood and more through a single window pane (Figure 85).

You should consider using combinations of construction materials that will allow the least heat transfer. Table VI gives the relative heat transfer resistance of several common building materials.

As to combinations of these, compare the total resistance to heat transfer of the two wall compositions in Table VII. Note that neither wall has insulation.

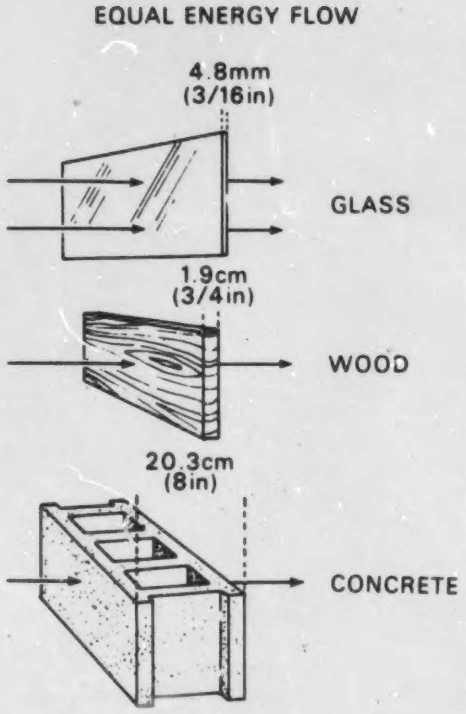

FIGURE 85. Heat loss varies through different materials.

4. EFFECT OF INSULATION

The type, amount and the way insulation is installed are all important in reducing heat transfer in and out of buildings. For example, you may have 15.2 cm (6 in) of insulation in your attic but have more energy loss than your neighbor whose house has the same amount (Figure 86). The reason is that different types of insulation have different insulation values. Another reason is that one house may have all the cracks and crevices covered while the other may not.

You learned from the last section the importance of selecting materials. Note the value of insulation in Table VIII as to resistance to heat transfer.

TABLE VI. RESISTANCE TO HEAT FLOW OF SOME COMMON BUILDING MATERIALS

Type and Material			Resistance to Heat Flow (R)*	
	(cm)	(in)	$\frac{m^2 °C}{W}$	$\frac{h \cdot ft^2 °F}{Btu}$
BUILDING BOARD				
Gypsum	0.95	3/8	0.06	0.32
	1.30	1/2	0.08	0.45
Plywood	0.64	1/4	0.05	0.31
	0.95	3/8	0.08	0.47
	1.30	1/2	0.11	0.62
	1.90	3/4	0.16	0.93
Wood Subfloor	1.90	3/4	0.17	0.94
MASONRY				
Concrete	15.2	6	0.08	0.48
	20.3	8	0.11	0.64
Concrete Blocks				
3 oval core sand and gravel	10.2	4	0.13	0.71
	20.3	8	0.20	1.11
Cinder	10.2	4	0.20	1.11
	20.3	8	0.30	1.72
Common Brick	10.2	4	0.14	0.80
Face Brick	10.2	4	0.08	0.44
SIDING				
Wood shingles	41	16	0.15	0.87
Wood bevel	1.3 x 20.3	1/2 x 8	0.14	0.81
Wood plywood	0.95	3/8	0.10	0.59
Aluminum or steel			0.11	0.61
FINISH FLOORING				
Tile, asphalt, linoleum, vinyl, rubber			0.008	0.05
Hardwood			0.010	
ROOFING				
Asphalt 0.95 (3/8)			0.08	0.04
built-up			0.06	0.33

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*$\frac{m^2 °C}{W}$ = (meters)^2°C ÷ watts

$\frac{h \cdot ft^2 °F}{Btu}$ = Hours (feet)^2°F ÷ British thermal units

TABLE VII. COMPARISON OF RESISTANCE TO HEAT FLOW OF MATERIALS AND TWO TYPICAL WALL SECTIONS

Frame Wall	Resistance to Heat Flow (R-Value)	
	$\frac{m^2 \, {}^\circ C}{W}$	$\frac{h \cdot ft^2 \, {}^\circ F}{Btu}$
Outside film 24 km/hr (15 mph) wind, winter	0.03	(0.17)
Siding, wood 1.3 x 20.3 cm (1/2 x 8 in lapped)	0.14	(0.81)
Sheathing 1.3cm (1/2 in) regular	0.23	(1.32)
Inside dead air space	0.16	(0.91)
Gypsum wall board 1.3cm (1/2 in)	0.08	(0.45)
Inside surface (winter)	0.12	(0.68)
Total Resistance	0.76	(3.43)

Masonry Wall	Resistance to Heat Flow (R-Value)	
Outside surface 24 km/hr (15 mph)	0.03	(0.17)
Face brick 10.2cm (4 in)	0.08	(0.44)
Cement mortar 1.3cm (1/2 in)	0.02	(0.10)
Cinder block 20.3cm (8 in)	0.30	(1.72)
Air space 1.4cm (3/4 in)	0.23	(1.28)
Gypsum board 1.3cm (1/2 in)	0.08	(0.45)
Inside surface	0.12	(0.68)
Total Resistance	0.86	(4.84)

TABLE VIII. RESISTANCE TO HEAT FLOW OF SOME COMMON INSULATION MATERIALS

Type of Insulation		Resistance to Heat Flow (R-Value)	
		$\frac{m^2 {}^\circ C}{W}$	$\frac{h \cdot ft^2 {}^\circ F}{Btu}$
Blanket and Batt: (fiberglass)	5.1-6.9 cm (2-2 3/4 in)	1.23	(7.00)
	7.6-8.9 cm (3-3 1/2 in)	1.94	(11.00)
	13.3-16.5 cm (5 1/4-6 1/2 in)	3.35	(19.00)
Loose Fill:			
Cellulose, per 2.54 cm (in)		0.65	(3.70)
Sawdust, per 2.54 cm (in)		0.39	(2.22)
Perlite, per 2.54 cm (in)		0.48	(2.70)
Mineral fiber (rock, slag, glass)			
7.6 cm (3 in)		1.58	(9.00)
11.4 cm (4 1/2 in)		2.29	(13.00)
16.5 cm (6 1/2 in)		3.35	(19.00)
19.1 cm (7 1/2 in)		2.23	(24.00)
Vermiculite, per 2.54 cm (in)		0.39	(2.20)

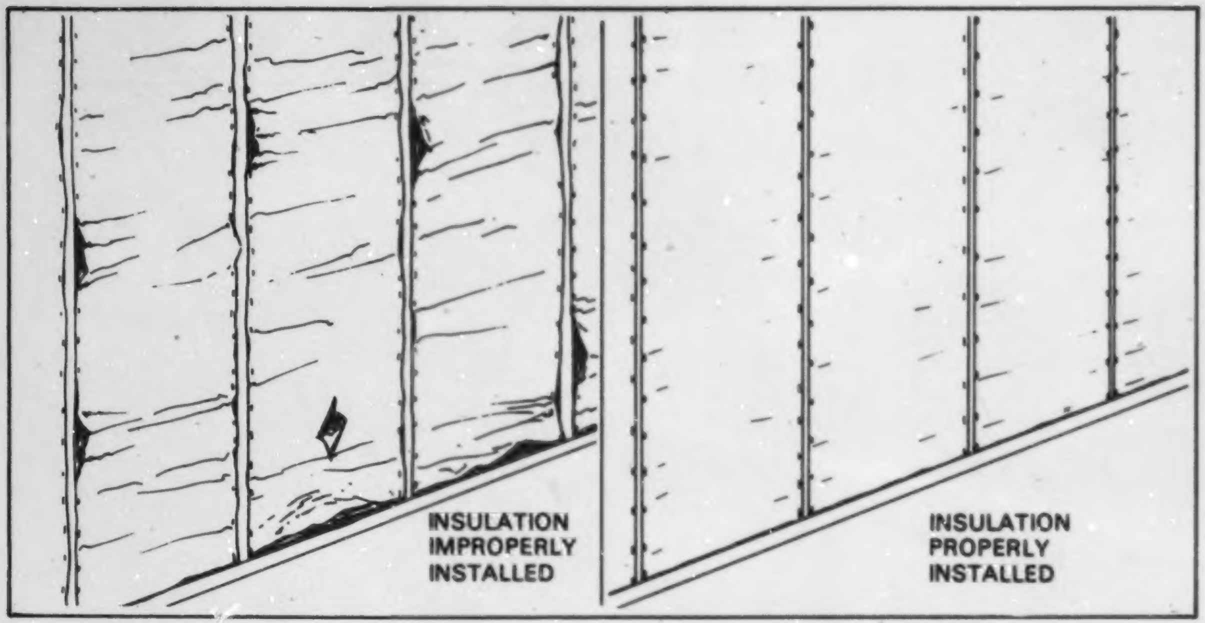

FIGURE 86. Two buildings with the same type and thickness of insulation may not have the same energy efficiency.

All types of insulation work on the principle that air is trapped in the spaces between particles or layers of a material. Trapped air is a poor heat conductor. Some insulators combine aluminum foil as a reflector with other insulating material. Aluminum foil reflects heat.

Insulation is available in a variety of forms, sizes and thicknesses. Loose-fill is one of the few types of insulation that can be used to insulate the walls of an existing building without removing the wallboard or plaster (Figure 87).

Loose-fill insulation consists of small particles of mineral wool, wood fibers, or vermiculite. This material can be poured from bags between ceiling joists in an attic, but in walls of existing houses special equipment is required to blow the insulation into the crevices. Adding proper amounts of loose-fill insulation to an uninsulated structure can easily reduce energy consumption by one-half.

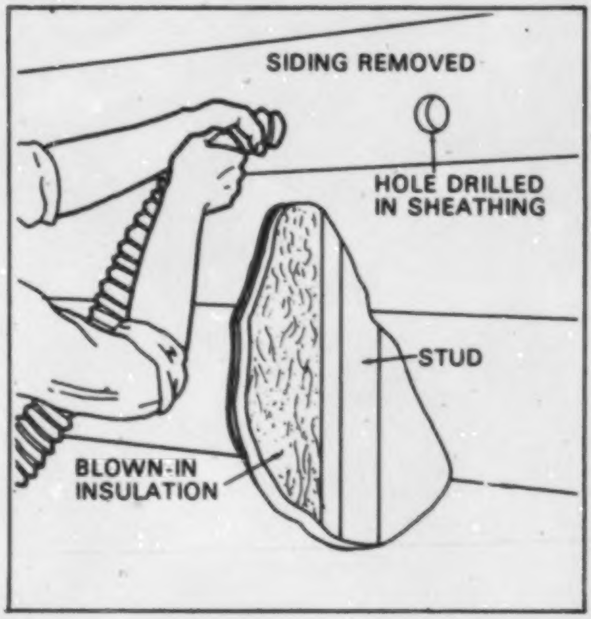

FIGURE 87. Loose-fill insulation may be blown in.

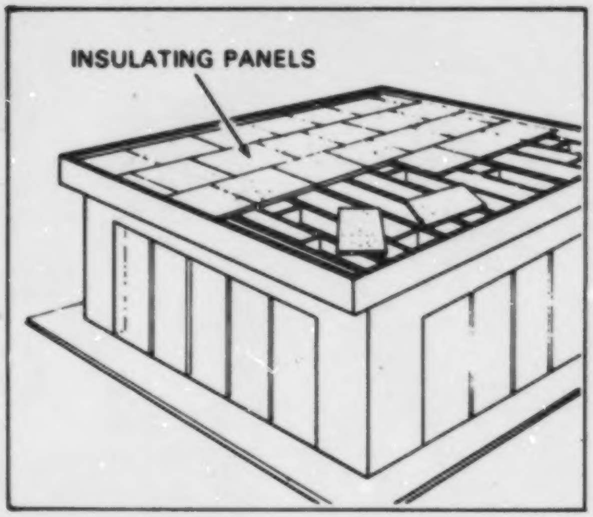

FIGURE 88. Styrofoam and compressed organic fibers come in rigid sheets.

Insulating panels of styrofoam, polyurethane and compressed organic fibers are effective materials when placed in proper locations in buildings (Figure 88). These panels are commonly used on flat roof decks being put in place before the final roofing.

They may also be added to the outside walls.

Flexible insulation is available in blankets and batts. These, too, may be of mineral wool, wood fibers, or fiberglass and come in varying thicknesses (Figure 89). Standard widths are 41 and 61 cm (16 and 24 in). Batt insulation is installed between exterior wall studs and ceiling joists in residences during construction.

5. EFFECT OF VAPOR BARRIERS

As warm air comes in contact with a cooler surface, such as walls and window panes, water vapor in the air condenses on the cooler surface. When insulation is used in walls and ceilings, moisture can condense on the inside surface of the insulation if an extreme temperature difference exists between the room and the outside. If this moisture works its way to the insulation, the insulation becomes a conductor of heat and loses much of its value. To prevent the passage of moisture from the interior of the room to the insulation, a vapor barrier is desirable. This vapor barrier is simply a layer of non-porous paper, plastic, or aluminum foil on the inside surface of the insulating material (Figure 90). Should moisture collect on the vapor barrier, it cannot pass through to the insulation and it eventually evaporates into the room. Thus the insulation in the wall remains dry and effective.

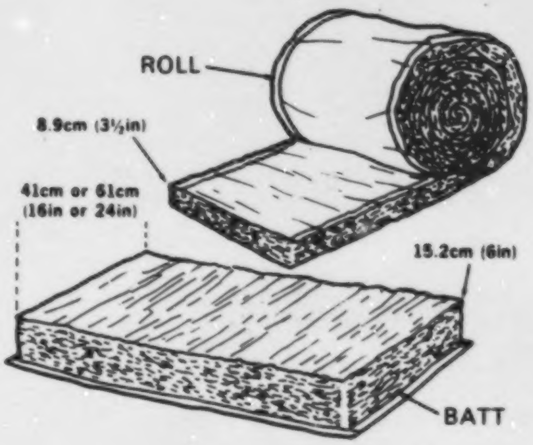

FIGURE 89. Insulation batts or fiberglass.

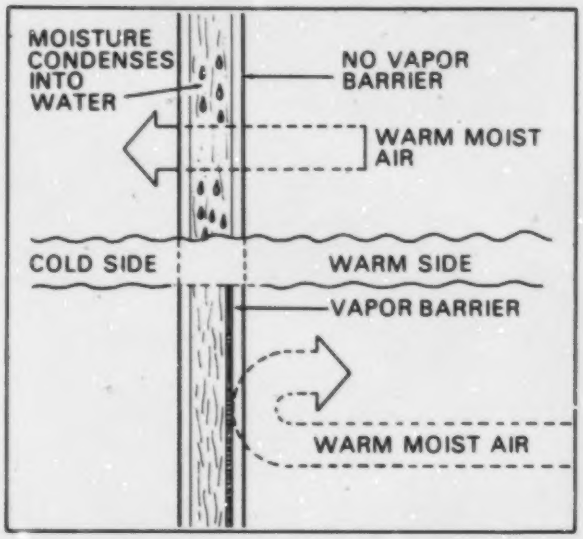

FIGURE 90. A vapor barrier is used to prevent condensation of water on the cool side of your house.

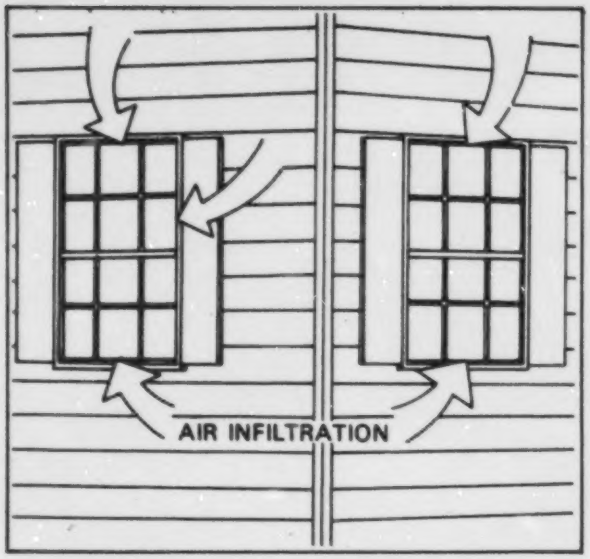

FIGURE 91. Much heat loss and gain in buildings is through air infiltration.

6. EFFECT OF WEATHERSTRIPPING AND CAULKING

Air infiltration is a robber of energy in buildings. No matter how much insulation you have, if there are cracks where cold air can get in, you are going to lose heat (Figure 91).

7. EFFECT OF WINDOWS AND DOORS

Glass is a poor insulator. So the more windows and doors you have, the more heat loss you can expect. For example, a house with several (shaded) windows will lose more energy than one with a few (Figure 92). Windows may be used to an advantage for heat gain if placed on the south side.

Windows and doors are installed to fit loosely enough so that they may be opened and shut with little effort. Therefore, there is always a crack around each window and door through which heat can escape and cold air can blow in. Even if a building is thoroughly insulated and furnished with storm windows and doors, the cracks and openings can add up to a large source of heat loss.

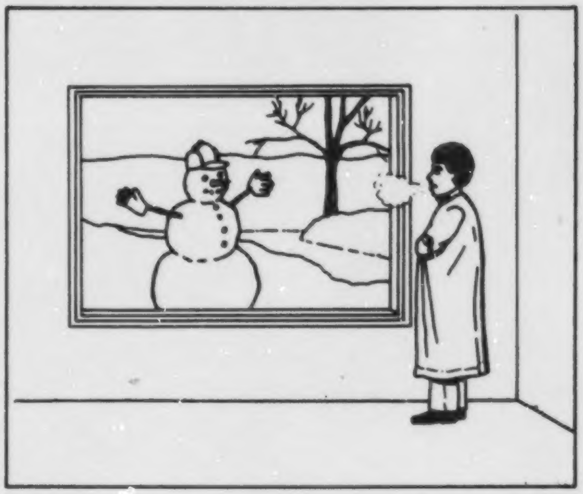

FIGURE 92. Windows have very little resistance to heat flow.

Cold window panes create a draft. The air is cooled by the cold window pane and the colder air sinks toward the floor, allowing the warmer air to move toward the window where it is then cooled. This cooled air also moves toward the floor causing a constant air motion away from the window, at floor level, and toward the window in the upper half of the room. A draft comes from the window and is sometimes confused with a draft blowing through a crack in the frame or between the window sash. Actually this "draft," or air motion, normally occurs although the cracks are sealed.

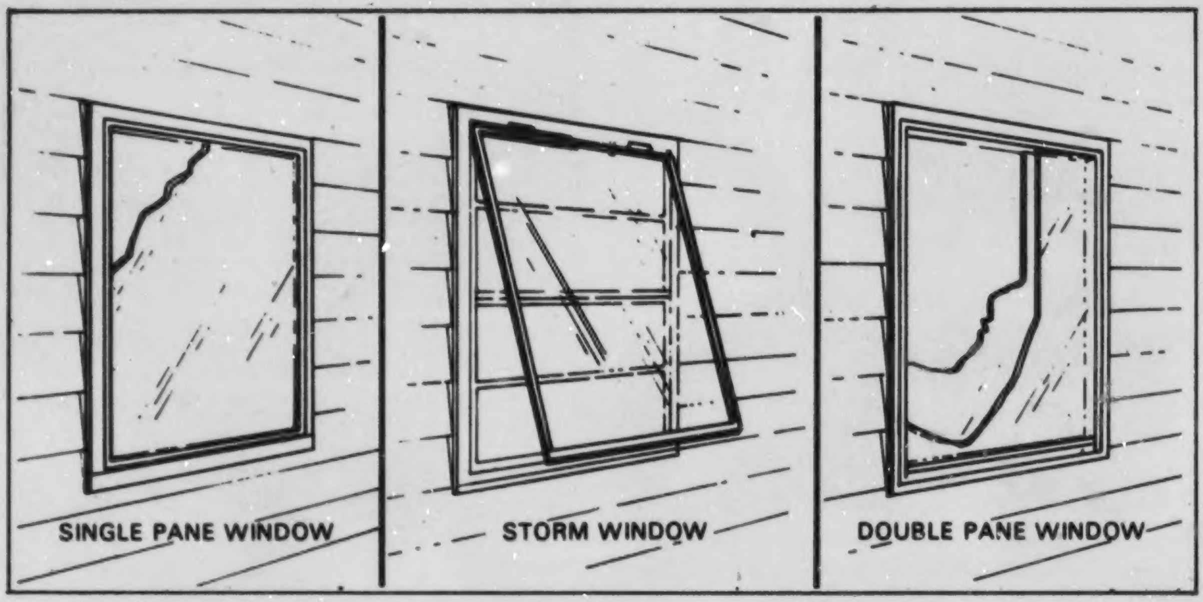

FIGURE 93. Storm windows or multi-pane windows save energy.

Storm windows or multi-pane windows help to eliminate this problem (Figure 93). They provide for air space which is resistant to conductive heat flow between two or three panes of glass.

8. EFFECT OF HEATING METHODS

The amount of energy used is directly related to the size of the house (Figure 94). You should consider heating and cooling only part of your home if it is very large.

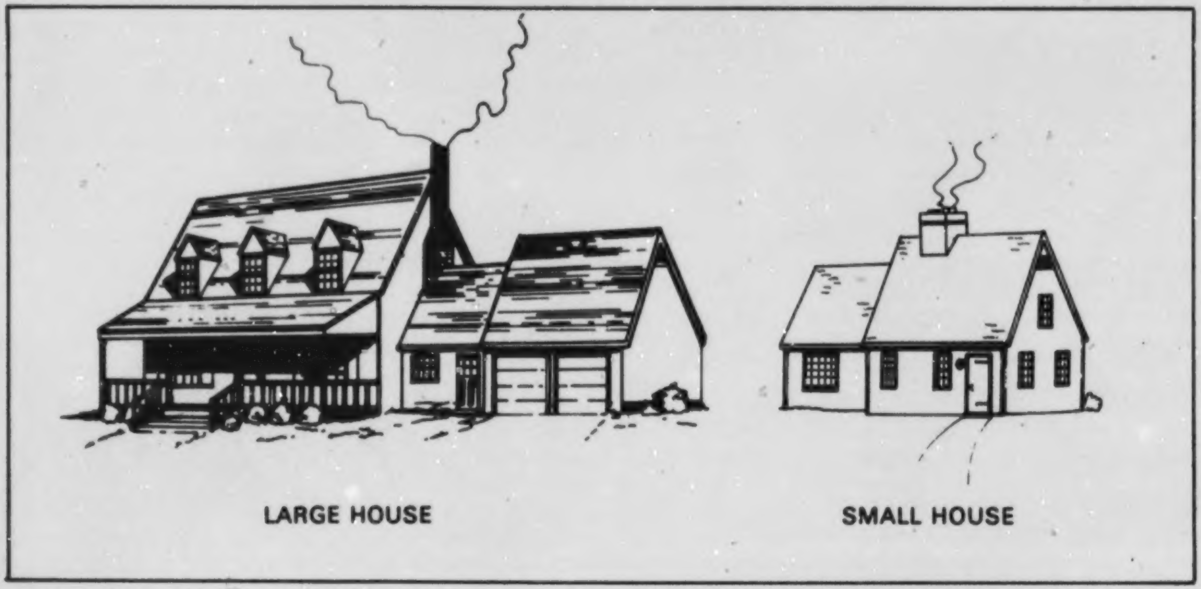

FIGURE 94. A large building will naturally use more energy than a small building.

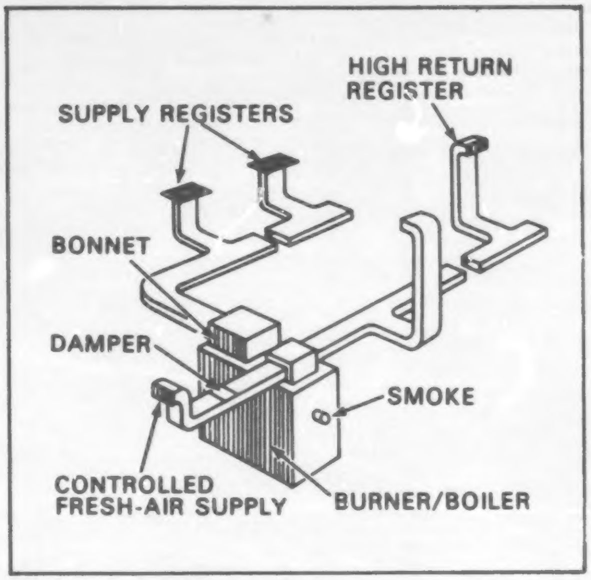

FIGURE 95. Forced air system.

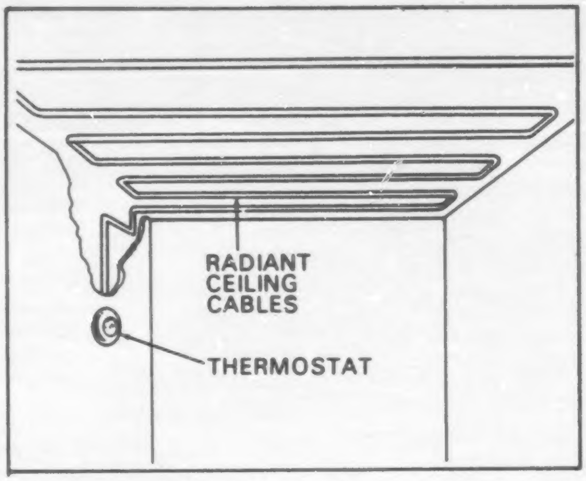

FIGURE 97. Electric radiant system.

All heating systems burn fuel, but some are more efficient than others. There is a difference in efficiency of equipment in some systems. But the main consideration is the cost of fuel, which may vary with your locality.

Heating systems generally used are as follows:

- Forced air (Figure 95).
- Hot water (hydronic) (Figure 96).
- Electric radiant (Figure 97).
- Electric resistance (Figure 98).
- Heat pump (Figure 99).
- Fireplace (Figure 100).
- Stove (Figure 100).

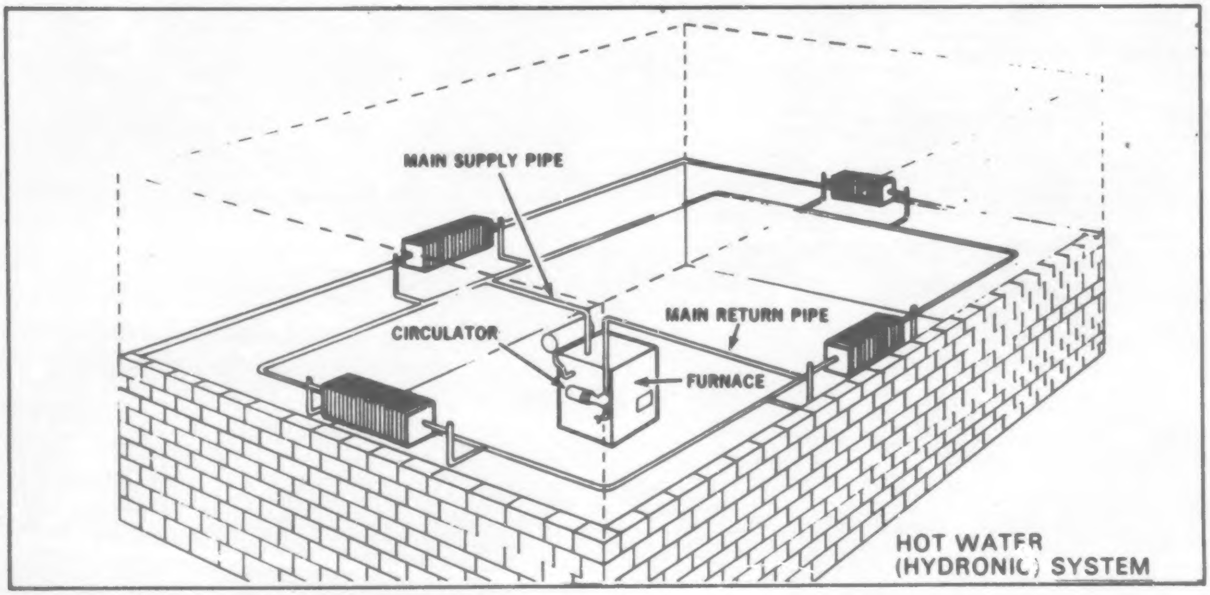

FIGURE 96. Hot water (hydronic) system.

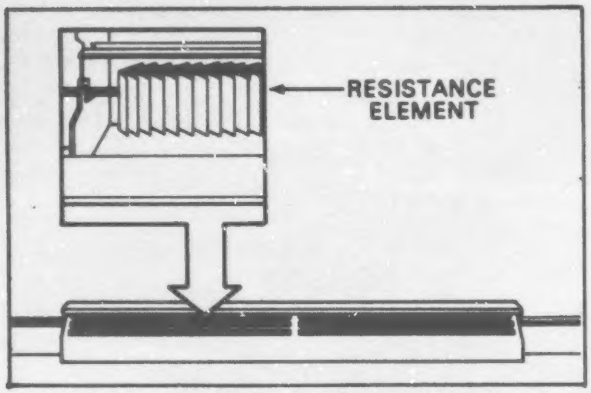

FIGURE 98. Electric resistance system.

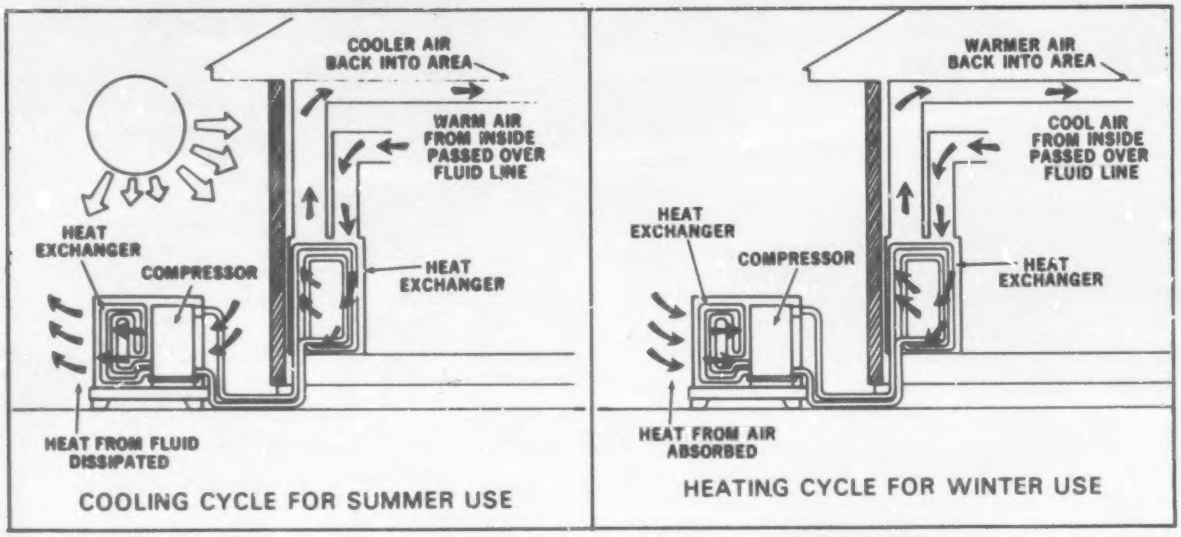
COOLER AIR BACK INTO AREA
WARM AIR FROM INSIDE PASSED OVER FLUID LINE
HEAT EXCHANGER
COMPRESSOR
HEAT EXCHANGER
HEAT FROM FLUID DISSIPATED
COOLING CYCLE FOR SUMMER USE
WARMER AIR BACK INTO AREA
COOL AIR FROM INSIDE PASSED OVER FLUID LINE
HEAT EXCHANGER
COMPRESSOR
HEAT EXCHANGER
HEAT FROM AIR ABSORBED
HEATING CYCLE FOR WINTER USE

FIGURE 99. Heat pump.

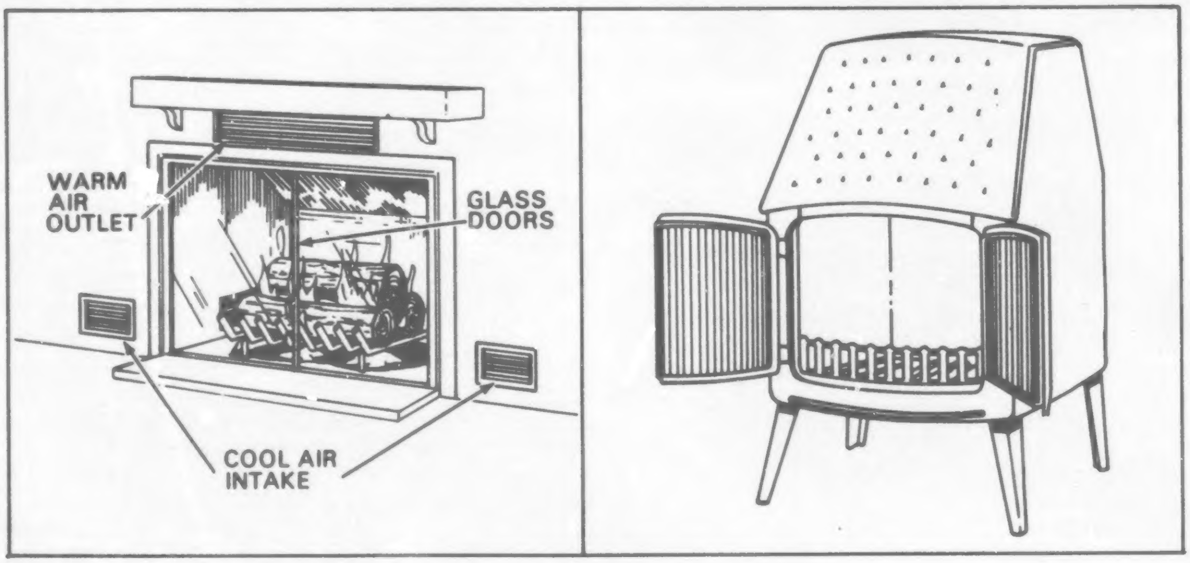

FIGURE 100. Fireplace and stove.

9. EFFECT OF AIR CONDITIONING

If you live in a temperate zone, you can expect to use about as much energy to cool your house as you do to heat it (Figure 101). Here you are trying to prevent heat on the outside from becoming equal to the temperature on the inside.

The same insulation is required. But direct sun light should be shaded from windows.

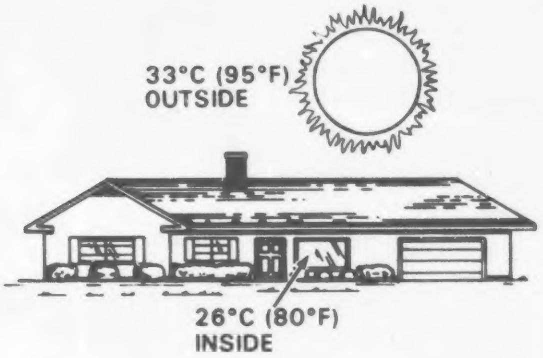

FIGURE 101. In some areas, it takes as much energy to cool a house in summer as to heat it in winter.

More and more, Americans are regarding air conditioning as a necessity, rather than a luxury. Even though air cooling is only 3% of the total national energy consumption, in the hot months it rises to about 42% of total energy consumption.

10. EFFECT OF VENTILATION METHOD

A certain amount of ventilation is required in a home. One reason is for comfort. Another is for cooling in summer. Particularly the attic should have an air exchange (Figure 102). Temperatures in attics may get as high as 60°C (140°F).

11. NEW METHODS OF HEATING AND COOLING

Passive solar systems are helping to reduce energy consumption.

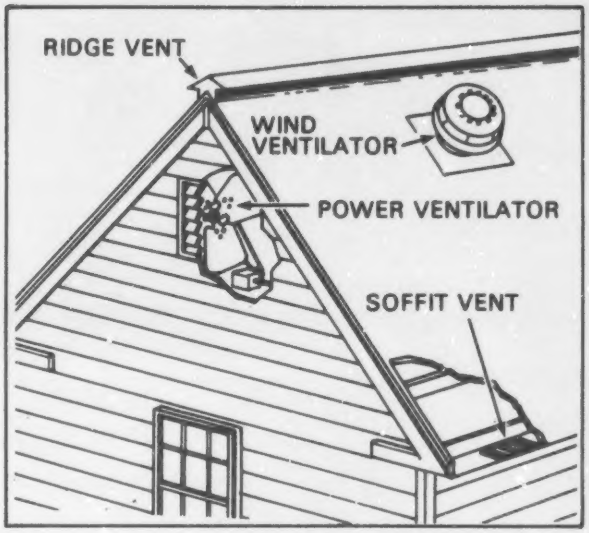

FIGURE 102. Attic cooling vents will save energy in summer.

12. EFFECT OF LIGHTING

Most of the energy used by lighting is in the form of heat. Since lights do supply some heat during winter, it is not so important to turn them off. But in summer, heat from lights works against the air conditioning system.

You can save energy by planning your lighting so that it is the most efficient (Figure 103). Fluorescent lights give more light for energy used than incandescent lights.

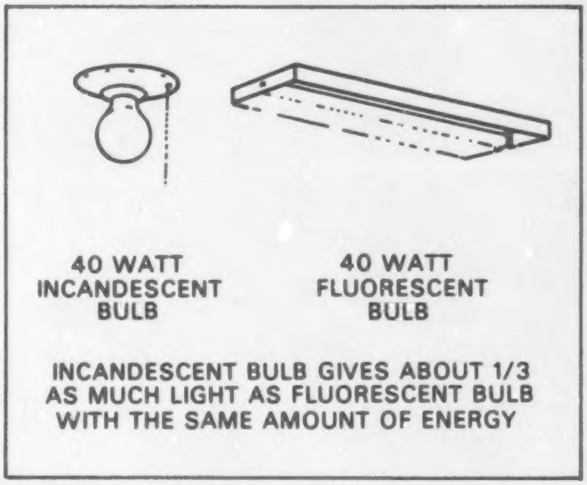
40 WATT INCANDESCENT BULB
40 WATT FLUORESCENT BULB
INCANDESCENT BULB GIVES ABOUT 1/3 AS MUCH LIGHT AS FLUORESCENT BULB WITH THE SAME AMOUNT OF ENERGY

FIGURE 103. Plan an efficient lighting system to save energy.

13. EFFECT OF PLUMBING

Plumbing can be designed to save energy. Dripping faucets lose energy, especially hot water faucets. It is usually not cost effective, however, to insulate residential pipes.

A water heater located inside the living area will help heat the house but will work against the air conditioning in summer (Figure 104). In any case, the water heater should be well-insulated.

When adding insulation to gas heaters, be sure to provide for air to the burner.

14. ENERGY-EFFICIENT APPLIANCES

Much emphasis is now being placed on the operating efficiency of appliances. When purchasing new appliances, you should compare efficiencies.

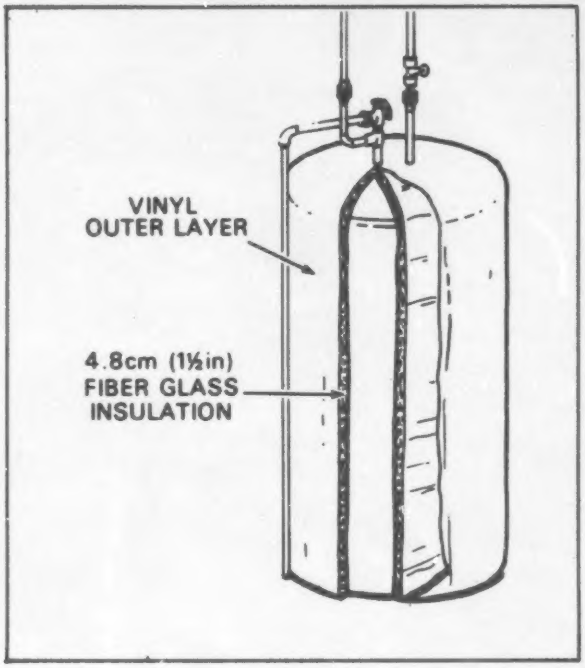

FIGURE 104. Water heaters should be well-insulated.

D. General Recommendations for Energy Efficiency in Residences

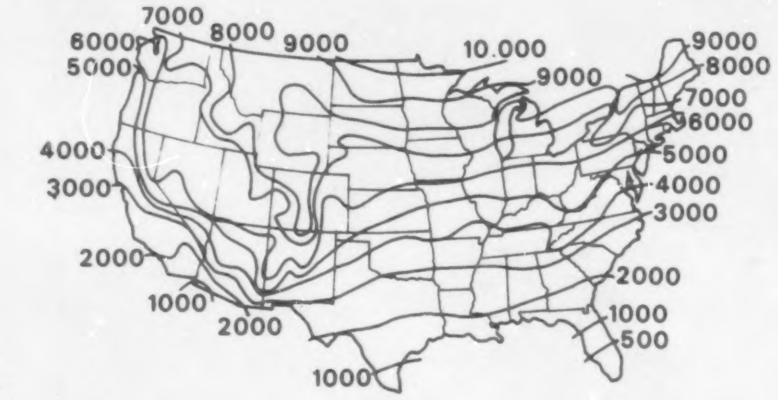

FIGURE 105. Winter degree days for different geographic locations.

General recommendations for improving the energy efficiency in your home are as follows:

1. Caulk all cracks and joists.
2. Weatherstrip all doors and windows.
3. Insulate heating and ventilating pipes and ducts if they are in unconditioned space.

   Use R_2 for pipes and R_4 for ducts.
4. Provide outside combustion air to all fossil fuel burners.

   This includes wood stoves and fireplaces.
5. Fit fireplaces with a glass-front seal.
6. Use only high-efficient heating, air conditioning and appliances. Heating systems should not be designed for greater than 15% oversize. EER ratings should be 8 or above.
7. Find winter degree days for your locality (Figure 105).

   For more specific information, contact your Energy Extension Office.
8. Select type of heating fuel you are using in column 2, Table IX.
9. Find R-value recommended for ceilings, walls and floors for your type of windows and doors.
10. Follow procedures in Parts Two and Three for computing more accurately the heat loss and gain and selecting and installing materials.

TABLE IX. GENERAL RECOMMENDATIONS FOR ENERGY EFFICIENCY IN BUILDINGS (HUD, 1978)

Winter Degree Days °F	Heating Fuel	Ceilings* R-Value		Walls* R-Value		Floors Over Unheated Spaces* R-Value		Foundation Walls of Heated Spaces* R-Value		Layers of Glazing: Windows and Glass Doors	Storm Door or Thermal Door
		SI	US	SI	US	SI	US	SI	US		
0 - 1000	Electricity	3.3	(19)	1.9	(11[a])	1.9	(11)	-	-	1	No
	Fossil Fuel or Heat Pump	3.3	(19)	1.9	(11[a])	-	-	-	-	1	No
1001 - 2500	Electricity	3.9	(22)	2.3	(13[a])	2.3	(13)	-	-	2	No
	Fossil Fuel or Heat Pump	3.3	(19)	1.9	(11[a])	-	-	-	-	1	No
2501 - 4500	Electricity	5.3	(30)	2.3	(13[a])	3.3	(19)	1.2	(7)	2	No[c]
	Fossil Fuel or Heat Pump	3.9	(22)	2.3	(13[a])	2.3	(13)	1.2	(7)	1	No[c]
4501 - 7000	Electricity	5.3	(30)	2.3	(13)	3.3	(19)	1.2	(7)	3[b]	Yes
	Fossil Fuel or Heat Pump	5.3	(30)	2.3	(13)	2.3	(13)	1.2	(7)	2[b]	No[c]
7001 or more	Electricity	7.0	(38)	2.3	(13)	3.3	(19)	1.2	(7)	3[b]	Yes
	Fossil Fuel or Heat Pump	5.3	(30)	2.3	(13)	3.3	(19)	1.2	(7)	2[b]	Yes

[a] Recommended only when wall covering is removed and an adequate vapor barrier is installed.
[b] Insulating frames should also be provided if replacement sashes are installed.
[c] Storm or thermal door is recommended if the primary door is hollowcore or over 25% glass.
*SI - R = $\frac{M^2 °C}{W}$; US - R = $\frac{h.ft^2 °F}{Btu}$

IV. Care and Maintenance of Energy-Efficient Buildings

Buildings are designed, built and maintained by people. Poor design leads to poor use of materials. Poor construction leads to high maintenance costs. From beginning to end, buildings require energy — energy we pay for.

An energy-efficient building must be built that way or renovated. To remain energy efficient, it must be maintained properly. The custodian or building engineer tries to maintain a building for the users. However, all building users should help to "maintain" the space they use. In addition to your home, if you consider all the buildings you use in a year, you will soon realize your responsibility for helping to save energy and maintain these buildings.

Following are some hints for maintaining energy-efficient buildings. We will start with the maintenance of a home and then consider the important factors in the maintenance of public buildings. They are discussed under the following headings:

A. Maintaining an Energy-Efficient Home.
B. Maintaining an Energy-Efficient Public Building.

A. Maintaining an Energy-Efficient Home

The key to year 'round comfort is a home kept in good condition. Energy bills and maintenance costs will be much lower if a home is checked both in the fall and spring. During these seasons you can open doors and windows without heat loss or gain and service heating and cooling systems which are not being operated. Outdoor repairs are also easier at these times of the year. Lists are given under the following headings:

1. Fall Check List.
2. Spring Check List.

1. FALL CHECK LIST

1. Check insulation wherever possible—unfinished crawl spaces or attics.

   Check thickness and condition. Damp insulation should lead you to discover the source of the problem. Make necessary improvements.

2. Look closely at weatherstripping and caulking around all windows and doors.

   Repair cracked or separated caulking and replace worn-out weatherstripping.

3. Clean and repair windows.

   Check weatherstripping and make sure windows operate easily. Check caulking around storms. Store screens to give maximum light for the winter.

4. Cover exterior portion of your air conditioner unit with a weatherproof sleeve during the winter.

5. Clean all gutters and drain pipes.

6. Service heating systems and heat pumps.

   Change filters, vacuum ducts and registers or radiators, and have service person do annual maintenance on burner units. Have chimneys cleaned.

7. Drain a few pails of water from the hot water heater to remove sediment.

   Extensive draining to clear the water may suggest rust problems or other deterioration.

8. Check and clean burner units on hot water heaters.

9. Replace washers on leaky faucets.

10. Check caulking around outside faucets and drain them so that the water won't freeze.

11. Check roofs for leaks.

    Use unfinished attic and/or damp insulation as a way to detect leaks. Replace any damaged tiles or roofing materials. With a finished attic, you can check from the outside.

12. Clean all lighting fixtures.

13. Check house siding for holes or cracks.

    Fill with caulking.

14. Check and clean your humidifier as recommended by the manufacturer's instructions.

15. Check fireplace damper to make sure it closes tightly.

    Have chimney cleaned.

16. Check insulation on pipes passing through unheated areas.

17. Store canvas awnings to prevent unnecessary wear.

18. Clean refrigerator and freezer coils.

19. Determine if off-peak-hour use of electricity is on proper schedule.

2. SPRING CHECK LIST

1. Check for winter damage to windows and doors.

   Caulk, weatherstrip and refinish if necessary. Check and replace screens. Store storms.

2. Check attic for any ventilation problems.

   Clean the attic to control dust and dirt circulation. Clean vents if necessary and check for insect nests. Power vents should be cleaned according to manufacturer's instructions.

3. Check outside of house for cracks, peeling paint and other damage.

   Schedule necessary painting.

4. Clean drapes and blinds and make sure they are in good working condition.

5. Reinstall summer awnings.

   Check and repair.

6. Remove winter cover from air conditioner.

   Clean or replace filter.

7. Switch off pilot light for gas or oil heat.

   Have service person do this if remote switch is not in use.

8. Clean dryer vent.

   Install one if this has not been done.

9. Check off-peak-hour schedule for use of electricity.

10. Check and clean stove hood and room fans.

11. Turn thermostats on heating systems to lowest position or "off" position.

12. Check seals on refrigerators and freezers and clean refrigerator coils.

13. Clean fireplace.

    With a screened chimney, the damper may be left open for better ventilation.

14. Check landscaping to determine if additional planting of shrubs or trees will help for shade or as a wind barrier.

15. Check basement.

    If basement is damp or moisture shows on walls, remedy the situation with a dehumidifier or special paint.

16. Put dehumidifier into service by cleaning according to manufacturer's instructions.

17. Check plumbing and make repairs.

B. Maintaining an Energy-Efficient Public Building

The diverse nature of commercial, institutional and industrial buildings makes it difficult to prescribe specific maintenance procedures to fit all situations. We are assuming that the building has been made energy-efficient. Primarily, this term refers to the way in which a building shell has been designed and constructed. Secondly, it refers to the selection of equipment needed to provide heat, air conditioning, light, water and other services. It also includes site development and landscaping. Energy-saving ideas for designing and constructing a building shell are given in the following summary.

Suggestions for selecting energy-efficient equipment to service a building were given in previous chapters. Now let us look at ways in which a maintenance program can be developed which will effect minimum costs and obtain maximum service and comfort for its users.

1. Establish a cooperative planning group.

   It should be representative of all personnel who have the responsibility for determining and scheduling the building's functions and use.

2. Establish a communication system.

   Management should readily express its plan for the building's operation by which employees and other public users can feed back ideas or complaints.

3. Develop a training program.

   Maintenance personnel should be introduced to the need and procedures required for energy conservation. This should be a continuous process to allow for ease in instituting new methods.

4. Develop a maintenance schedule.

   It should be inclusive of all aspects of the service equipment, building shell and landscaping.

5. Match training and skills of maintenance personnel with the required tasks.

   Place one person in charge of each of the categories indicated in Number 4.

6. Use the information from the chapters and categories in this book.

   Develop detailed plans and procedures for the care and maintenance of the building in question. Building management and custodial personnel have this responsibility.

7. Use engineering and other energy consultants.

   Get help to solve problems peculiar to the building in question.

8. Keep records of the cost benefits resulting from your energy conservation efforts.

   Publish summaries of these results in annual reports, local newspapers and national trade journals.

9. Support school and community efforts to develop energy conservation habits.

   Public users and employees of any establishment can contribute greatly to the maintenance or deterioration of an energy-saving program.

10. Spread the word.

    Your energy-efficient building and program should be publicized through public talks, conventions and associations.

V. Developing Energy-Saving Habits

You have been considering one of the most difficult problems facing our nation —energy consumption. Demand for energy is becoming greater than U. S. sources and those of the world.

Certainly, alternative energy sources must be found. Conservation is the most immediate source of energy we can tap. It will not be easy to develop energy-saving habits because it will mean a new lifestyle for most people—especially for those who presently consume the most.

If you apply the information in this course, you will have the basis for our new energy-saving habits. This section simply lists a few of the various techniques for saving energy in two main areas:

A. Practicing Energy-Saving Techniques in the Home.

B. Practicing Energy-Saving Techniques at School or in Other Buildings.

The following tips for conserving energy at home are in most cases an easy and effective place to start. Each member of the family will no doubt take responsibility for particular tasks and perhaps develop new conservation methods.

Suggestions are given under the following headings:

1. Heating.
2. Air Conditioning.
3. Lighting.
4. Refrigerators and Freezers.
5. Dishwashers.
6. Ovens and Stoves.
7. Clothes Washers and Dryers.

A. Practicing Energy-Saving Techniques in the Home

1. HEATING

1. Keep all parts of the heating system clean.

   This includes filters, ducts, vents, blower fan and thermostat.

2. Be sure thermostat is placed where it will not be affected by cold drafts or heat-producing sources such as TV's or lamps.

3. Turn the thermostat to its lowest settings when gone for more than a day.

   Shut heating system off completely in warmer seasons.

4. Lower the thermostat to 20°C (68°F) for the day, and 16°C (60°F) for the night (10 p.m. to 6 a.m.).

   From a 22°C (72°F) reference setting, this could save as much as 20% on winter heating in Minneapolis and 48% in Atlanta.

5. Use an electric blanket at night.

   Set the thermostat at 16°C (60°F). This is much cheaper than running the heating system at daytime temperatures.

6. Set the thermostat no higher than the desired temperature when a room has been cool.

   It may be forgotten and overheat your home.

7. Use drapes or insulated shades to avoid heat loss through windows.

8. Heat only those rooms you use frequently.

   Close doors to unheated rooms.

9. Use a fireplace sparingly unless its efficiency has been recently improved.

   Close damper when fireplace is not in use--warm air can be sucked up the chimney.

10. Maintain proper humidity in a house.

    Dry air feels cooler than the actual temperature setting.

11. Keep heating vents free from obstructions.

    Move such obstructions as drapes, furniture, shelves or radiator covers.

12. Check out heat-saving gadgets.

    They may improve your heating system, so make sure they can be operated safely and comply with all local building codes.

2. AIR CONDITIONING

1. Use a ceiling mounted fan and a well-ventilated attic.

   It will draw cooler evening air through windows and exhaust hot air as a method for reducing cooling costs.

2. Adjust room air conditioner vents upward.

   This position allows for the best circulation and cooling of the warm air near the ceiling.

3. Close heating system registers when using a room air conditioner.

   This practice will prevent cool air loss through basement ducts.

4. Avoid unnecessary lighting as it gives off heat which requires cooling.

5. Use shades and drapes to keep out solar radiation and retain the cooled air.

6. Keep windows closed and use doors sparingly.

7. Use attic ventilation system to remove heat which would filter down and warm the rooms below.

8. Keep such devices as lamps and hot plates away from the air conditioner.

9. Keep the outside portion of the air conditioner unit free from direct sunlight, leaves, etc.

   Use a fence or shrubs to provide shade. Mount on north side of house when possible.

10. Keep indoor cooling vents free from furniture and drapes.

11. Use kitchen and bathroom vents only long enough to remove excess moisture and odors.

    Prolonged operation removes cooled air.

12. Use a timer to turn on air conditioner shortly before returning home from work to avoid unnecessary cooling during the day.

13. Turn off air conditioner when you are gone for several days.

14. Set air-conditioning thermostats no lower than 78°F.

    A 78-degree setting versus a 72-degree setting could lower cooling cost by over 40%.

3. LIGHTING

1. Make the best use of natural lighting.

   Place desks and other work areas near windows. Skylights can serve the same function as windows.

2. Light-colored paint on walls and ceilings and bright wallpaper will reflect available light for better lighting efficiency.

3. Avoid excessive lighting.

   Use light fixtures which direct light exactly where you need it—track lights, spot lights, lamps—in preference to general ceiling lights.

4. Use fluorescent and HID lamps wherever practical in halls, baths, kitchen counters.

5. Install dimmer switches and three-way bulbs to allow for lower intensity when desired.

6. Replace darkened bulbs as they give off less light.

   Use them in garages and basements.

7. Dust light fixtures regularly.

8. Turn off incandescent lights when you leave a room, even if only for a few minutes.

   Fluorescent lights can be left on if you will return to the area within 15 minutes.

9. Use automatic switches or red pilot lights for basements, garages and closets.

   They will make sure that lights are shut off.

10. Security lights outdoors or indoors should be automatically controlled by photoelectric cells or clock timers to save energy during daylight.

11. Select lights and fixtures which have good reflective qualities as well as good looks.

4. REFRIGERATORS AND FREEZERS

1. Use only a cold enough setting to keep ice cream firm and milk cold.

2. Plan to take out as many items at one time as you can.

3. Defrost non-frostfree models often enough to avoid excessive ice buildup which can act as an insulator.

4. Keep freezers and freezer compartments filled to prevent extra warm air from entering when opened.

   Place water-filled milk cartons in empty spaces.

5. Leave air space between items in refrigerator to allow for free air circulation.

   Use to capacity, however, and don't block air vents.

6. Use the power-saver or economizer if the unit is so equipped.

7. Avoid excessive moisture by covering liquids.

   Moisture causes the unit to work harder.

8. Hot dishes should cool to room temperature if possible before being placed in refrigerator.

9. Older refrigerators are less efficient.

   Use them as backup units only when needed.

10. Freeze only 2-3 pounds per cubic foot of capacity at one time to avoid prolonged operation.

5. DISHWASHERS

1. Wash only full loads.

2. Prerinse dishes when they are to be left until dishwasher is full.

3. Use hot water no higher than 150°F.

4. Follow the manufacturer's directions for loading so that soiled parts face the washing action.

5. Measure detergents properly.

6. Allow dishes to air dry when possible.

   Most units now have a convenient selector button for this.

6. OVENS AND STOVES

1. Use as small amount of water as is necessary.

   Small amounts heat more quickly. Use a steamer rack.

2. Make sure the pan fits the size of the burner.

   A small pan should be used on a small element. It may be possible to adjust the element setting or gas flame to fit the pot size you are using.

3. Boil water in a covered pot.

   This provides a 20% savings since it boils faster.

4. Use thawed or partially thawed food.

   It cooks sooner.

5. Bake as many items at one time as you can.

6. Clean pans.

   Dirty, dull pans won't be as efficient to cook in as clean, shiny ones—especially in electric cooking.

7. Use stove-top elements to cook foods which cook in a short time and the oven for foods which take a long time.

   An electric range uses 1.5 kilowatts per hour and an oven uses 5 kilowatts per hour.

8. When cooking, bring water to a quick boil and then turn down to the lowest setting needed.

9. Use a microwave oven whenever possible, if you have one.

10. Do not pre-heat the broiler or the oven unless absolutely necessary.

11. Use a lower temperature (usually 25° less) when you use a glass or ceramic dish.

12. Do not use your range or oven to heat the kitchen.

13. If you use a self-cleaning oven, activate it right after you have been baking.

14. Use the smaller of two ovens whenever possible in a double oven unit.

15. Use copper, stainless steel and cast iron pots.

    They require lower temperature settings than does aluminum.

16. If you have a pressure cooker, use it whenever possible.

    It saves time and energy.

17. Turn off an electric range 5 minutes ahead of time.

    The food will continue to cook as the unit cools.

18. Use smaller cooking appliances such as toaster-oven, crockpot, electric frying pan.

    They consume less energy than a range for many cooking tasks.

19. Keep reflector pans under surface units on your electric range clean to improve their efficiency.

20. Whenever possible, keep the oven door closed while baking.

    As much as 20% of the heat can be lost with one opening.

21. Do not use aluminum foil to line your oven unless manufacturer's instructions permit it.

    Reduced circulation and efficiency can result.

7. CLOTHES WASHERS AND DRYERS

1. Use the least amount of water for the washing job to be done.

   Water-level controls are available on many machines.

2. Do not overload your washer.

   If you do, the machine has to overwork and will not operate efficiently.

3. Use warm or cold water whenever possible.

4. Clean the lint filter after each load.

5. Sort clothes by color and fabric.

   Wash similar items together. You will save on hot water and electricity.

6. Take care in the amount of detergent you use.

   Too much can overwork your machine.

7. Try to run the dryer only when you have full loads.

8. Do not overdry the clothes.

   This wastes energy, causes wrinkles in clothes, and fabrics may even wear out sooner.

9. If your dryer has a heat-sensing control or timer, be sure to use it to avoid overdrying.

10. Run drying loads of similar fabrics.

    Some fabrics require a shorter drying period than others.

11. Dry clothes in consecutive loads to retain heat from one load to the next.

12. Clean the lint filter after each load.

13. If clothes must later be dampened for ironing, do not completely dry them in the dryer.

B. Practicing Energy-Saving Techniques at School or in Other Buildings

Your knowledge and practice of energy conservation can make a major contribution to solving our energy problems. The following tips for saving energy can be applied in schools and other buildings. Whatever the method used, it will require the cooperation of all persons involved.

Suggestions are given under the following headings:

1. General.
2. Heating and Cooling.
3. Lighting and Electricity.
4. Building Design and Renovation.
5. Extra Activities.
6. Food Services.

1. GENERAL

1. Involve everyone at his or her level.

2. Establish guidelines for energy conservation.

   Involve everyone and take in all facets of an educational program or business.

3. Evaluate present systems and methods and recommend short and long-range changes.

4. Provide a clearinghouse for information and procedures.

5. Determine energy needs for a recent specific time.

   Use this as a basis for comparison to project future action.

6. Make use of surveys which have been done on energy use.

7. Insure that future building plans are based on conservation as well as educational and aesthetic features.

8. Remind people that energy conservation begins in a small way on an individual basis.

9. Launch a public relations program to broaden understanding of the situation.

10. Develop a cooperative effort among schools, business, industry and the community.

11. Encourage an exchange of ideas from all levels.

12. Teach energy usage and conservation as part of the curriculum or training program.

13. Urge purchase and use of equipment which uses energy most efficiently.

14. Consider alternatives to the traditional school year or working week to make optimum use of non-energy-consumptive months and space available.

2. HEATING AND COOLING

1. Review school calendar.

   Extend school days in the time frames which require the minimum use of heating fuels as related to heating degree days.

2. Establish a standard thermostat setting that will not interfere with learning or working situations.
3. Provide for an individual thermostat in each room or work area so as to efficiently control temperature.
4. Reduce to a minimum the heat in auditoriums and gyms.
5. Check room partitioning so that intake and outlet air flow is not restricted.
6. Reduce temperatures after regular programs or work hours.
7. Curtail work activities beyond normal school day.
8. Consolidate work areas.
9. Consolidate essential after-hour programs.
10. Clean all air intake filters periodically and service regularly.
11. Insure boiler efficiency by periodic cleaning and proper water treatment to prevent scale.
12. Insure burner efficiency by proper mechanical operation, proper fuel and air mixture (best jet device) and periodic cleaning.
13. Check stack temperatures to preclude the loss of heat in the combustion process.
14. Insure that all valves in the heating system function properly, and check for leaks in the system.
15. Insure that all vacuum and condensation-return pumps function properly.
16. Balance heating and air conditioning systems to minimize hot and cold spots in the building.
17. Investigate energy efficiency as part of the criteria when purchasing heating or cooling equipment.
18. Schedule all evening meetings for one building at common times.
19. Replace older non-efficient heat-producing electrical devices with new solid-state (cooler) devices.
20. Provide facilities of a size appropriate to the needs of a group.
21. Investigate the use of dimmer switches for regulation of lights in areas not commonly used.
22. Lower ceilings, where possible, to reduce air space for heating.
23. Draw shades and curtains at night to retain heat.
24. Check and refurbish insulation and weatherstripping.
25. Keep windows and doors closed to retain heat.

26. Turn off heat in stairways and hallways.

3. LIGHTING AND ELECTRICITY

1. Replace older incandescent (heat-producing) lighting systems with fluorescent (cooler) systems or HID lamps.
2. Minimize the length of time artificial light is used.

   Use windows and skylights to good advantage.

3. Shut off banks of light nearest natural light sources when not needed.
4. Consider fewer bulbs with higher wattage when designing a lighting arrangement.
5. Develop specifications for electrical equipment which emphasize minimal energy use.
6. Operate every other fluorescent tube in a bank of fluorescent lights.
7. Investigate new lighting systems (both electrical and natural) for incorporation into present buildings.
8. Keep fluorescent tubes clean.

   The dirt they attract will reduce lighting efficiency.

9. Shut off lights when not in use.
10. Schedule large power-consuming activities for off-peak hours.
11. Schedule cleaning for daylight hours whenever possible.

    At night, use lights only in the rooms being cleaned.

12. Investigate the use of timers on electrical devices.
13. Regulate and reduce the use of non-essential appliances.
14. Use paints which reflect light without glare.

4. BUILDING DESIGN AND RENOVATION

1. Consider energy as important in design as educational function and aesthetic features.
2. Modify existing buildings in well-planned phases.
3. Utilize a variety of consultants in all planning groups.
4. Plan alternate lighting systems with a reexamination of recommended standards.
5. Review present methods of insulating buildings.
6. Install storm windows or insulated glass.
7. Examine and repair weather-stripping.
8. Select heating and air conditioning units which are most efficient.
9. Air conditioning systems for short term use may be unnecessary.
10. Landscape for minimal energy use in upkeep and maximum protection of building from weather.
11. Position classrooms and offices for minimum exposure to wind, direct sunlight, and noise.
12. Minimize glass area.

13. Consider lower ceilings.
14. Replace inefficient older equipment with new equipment.
15. Plan to reuse waste heat when possible.
16. Plan a light, efficient and comfortable decorating scheme.

5. EXTRA ACTIVITIES

1. Centralize necessary evening classes.
2. Eliminate non-essential evening classes.
3. Reschedule as many club and activity groups during a "free period" of the regular day schedule or just after school.
4. Review athletic schedules to keep activities within a certain mileage range.
5. Reschedule night games to afternoons.
6. Use smaller vehicles for driver education classes.
7. Schedule athletic or other after-school activities simultaneously.

6. FOOD SERVICES

1. Centralize food preparation.
2. Route service vehicles efficiently.
3. Employ faster cooking methods—pressure cooking and microwave.
4. Use cold water when possible for washing.
5. Replace inefficient, obsolete equipment.
6. Employ menus that reduce the amount of cooking necessary.
7. Use as many manual devices (can openers) as practicable.
8. Defrost refrigerators manually.
9. Minimize snacks and snack time.
10. Plan baking to use ovens to capacity and efficiency.
11. Encourage use of cold lunches.
12. Check cleanliness of refrigeration coils and other factors which use extra energy.
13. Use prepared foods unless the cost is prohibitive.
14. Minimize temperature on steam tables and warming ovens.
15. Thaw frozen foods before cooking.

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